# Comparison of Piped and Open Channel Distribution of Irrigation Water Supplies

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Published by
The Ritso Society (Inc)
PO Box 75, Darfield, Canterbury

August 2007

ISBN 978-0-478 31113-6 (Print)
ISBN 978-0-478-31114-3 (Online)

This publication is available on the following websites:
The Ritso Society: http://www.ritso.org.nz
The Sustainable Farming Fund: http://www.maf.govt.nz/sff/
Irrigation New Zealand: www.irrigationnz.co.nz
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# The Ritso Society

The Ritso Society was incorporated on 3 April 2002

The key objectives of the society are:

- To promote and develop knowledge and understanding of water enhancement schemes on the Central Canterbury Plains between the Waimakariri River to the north and the Rakaia River to the south ("Central Plains");
- To represent the interests of the Central Plains primary producers on issues and statutory decisions pertaining to the allocation and use of water;
- To raise awareness in Central Plains of the potential that irrigation brings for economic development;
- To promote and develop knowledge and understanding of the issues associated with the use of irrigation and associated land use change.

Membership of the Ritso Society includes business people, primary producers and others with an interest in promoting the economic well-being of Selwyn District and the wider Canterbury region.

The Ritso Society is named after Mr GF Ritso, who served as county engineer for Malvern during a period late in the nineteenth century, and in 1883 wrote:

> *"No doubt, in a few years, works will be constructed for the purpose of using the waters of all principal rivers for irrigating the plains, thus making water meadows which will fatten probably five or six sheep, or a proportionate number of cattle to the acre, on land two acres of which will barely support one sheep."*

The Ritso Society acknowledges with thanks the Ministry of Agriculture and Forestry Sustainable Farming Fund, Central Plains Water Ltd., Amiantit and Meridian Energy for their financial support of the project and the many farmers and community and professional people who gave so generously of their time.  We also acknowledge the authors of the report and Dr Terry Heiler of Irrigation NZ who managed the project on our behalf.

**Ross Keeley**
Chairman, The Ritso Society
August 2007

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# Preface

This report on the methodology for comparing the pros and cons of piped versus open channel irrigation water distribution systems has been prepared under the auspices of The Ritso Society and managed by Irrigation NZ Inc (INZ). It provides a comprehensive guide for communities and developers interested in making a choice between piped and open channel irrigation water distribution systems in feasibility investigations, or in situations where there is consideration of converting existing open channel systems to pipes.

As described in the report, the relative importance of the technical, economic, social and environmental merits and demerits of either distribution option, is very much site specific. In order to inform the generic issues involved in the comparison, the report takes a case study approach – learning about the generic by doing the specific. The study concluded that this can be a valuable methodology for advancing understandings of the complex and interrelated issues involved.

The main finding of the study was that piped distribution may be a more attractive long term option, in specific situations where there is sufficient gravity head between points of supply and demand areas. In the case studies investigated, results indicate that situations with land gradients greater than about 1 in 170 would benefit from a detailed analysis. Gradients in excess of this value exist over a good deal of the drier eastern seaboard of NZ where irrigation opportunities exist.

The material presented in the report reflects the considerable experience and understandings of the project team, and is believed to be the first of its kind in NZ where the generic issues have been deliberately surfaced by the case study approach.

The project received funding support from the Sustainable Farming Fund under the Ministry of Agriculture and Forestry (MAF), Central Plains Water Ltd, Meridian Energy and the Amiantit Corporation based in Saudi Arabia. This support is gratefully acknowledged.

The project team responsible for the development of the report included Ian McIndoe and Rose Edkins, Aqualinc Research Ltd.; Craig Scott of Riley Consultants Ltd.; Sue Cumberworth of The AgriBusiness Group and Dr Nick Brown, economist. Dr Terry Heiler of INZ managed the project on behalf of The Ritso Society.

The report of the project will be made available free of cost through the web sites of MAF, INZ and The Ritso Society, with CD and hard copies available from INZ at cost and by request.

On behalf of the irrigation community of stakeholders, I congratulate the project team on completing this work and breaking new ground in the process.

Dr Terry Heiler
Chief Executive
Irrigation NZ Inc.
August 2007

# COMPARISON OF PIPED AND OPEN CHANNEL DISTRIBUTION OF IRRIGATION WATER SUPPLIES

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## Annex 1: Generic Information Derived from the Case Studies



## Appendices:

# COMPARISON OF PIPED AND OPEN CHANNEL DISTRIBUTION OF IRRIGATION WATER SUPPLIES.

## SUSTAINABLE FARMING FUND and THE RITSO SOCIETY

Extension to Project SFF 05-117: Irrigation Scheme Sustainability Code

# SUMMARY REPORT

## 1.0 Background

In many of the large water enhancement schemes under investigation in New Zealand, it is possible to distribute water from the source of supply to user points by utilizing gravity head. The options for gravity distribution are open channel or large diameter pipes. In some existing schemes built some 50 years ago, options for replacing existing open channels with pipes are being investigated.

The reasons for contemplating piping rather than open channels are many and complex, and site specific. Communities faced with an assessment of the merits/demerits of the choice have identified the need for a systematic methodology that would allow informed choices to be made

This development of a methodology to address this situation was incorporated in the Sustainable Farming Fund supported project (SFF 05-117) whose main objective was the development of an Irrigation Code of Practice. It became clear that the work needed to develop a robust methodology for pipes and open channel comparison was in excess of the resources of SFF 05-117, and an application to extend the scope of the original project was developed and subsequently approved.

The agreed extension of project SFF 05-177 deals with the development of a generic methodology to allow a robust comparison of open channel and piped distribution systems for large scale irrigation schemes, in the NZ context, hereafter called the Project.

Milestone 1a of the Project was a report of an international literature search for investigations of the pros and cons of open channel and piped systems for large scale irrigation flows. The report on the literature search is included as Appendix 1.

Milestone 2a relates to a detailed case study of options in the context of the proposed Central Plains Water Scheme (CPW), and Milestone 2b was to investigate the conversion of three existing distribution channels in the Ashburton Lyndhurst Irrigation Scheme (ALIS) to a piped system. The detailed technical analyses of these two case studies are included as Appendixes 2, 3 and 4.

The general issues and suggestions regarding estimation of capital costs are dealt with in Appendix 5, which also applies these suggestions to the capital cost estimates for each of the open channel and piped options in the case studies.

The rationale behind the case study investigations was that the conduct of the work would surface important generic issues applicable to other circumstances where the options are an issue, and inform the development of the generic methodology, which is the main objective of the project. The generic technical aspects of the Project are included as Appendix 7 – Technical Issues Related Piped and Open Channel Systems. The suggested approach to economic cost comparisons and the Case Study economic results are contained in Appendix 6. These appendixes will be useful for others investigating the piped/open channel options in different circumstances, as will the detailed case studies where the use of the general approaches are illustrated by way of examples.

An important part of the project was to investigate the position of the rural communities involved in the case studies to the social, environmental and cultural issues involved – Milestone 4a. This investigation is detailed in Appendix 8.

An unedited version of the draft final report was reviewed at a meeting held at MAF Policy offices in Christchurch on 13 June 2007. The report of this meeting is included as Appendix 9, and the main suggestions have been included in this final report.

This Summary Report includes the major findings of all the detailed work reported in the appendixes. Annex 1 to the Summary Report draws some general conclusions from the work. It is intended for the general reader, and where findings are presented, they are referenced to the relevant sections of the detailed appendixes.

# 2.0 The Case Studies – General Features

## *2.1 Objectives of Case Studies*

The objectives of CPW investigation of the piped/open channel distribution options were to allow a robust comparison of capital costs, annual costs for operation and maintenance, costs of energy for on farm pumping, estimates of the value of water savings and different easement and land footprint needs, and to identify any non-quantifiable attributes of each option that should be considered in the assessment of the worth of both options. An associated objective was to identify key issues that needed to be incorporated in a generic methodology. The ALIS case study objectives were to assess the merits/demerits of changing an existing open channel supply race system to a piped supply.

## *2.2 Design Criteria*

It was decided at the start that the comparison of options should be based on designs that delivered, as far as possible, the same level of service delivery for each option. As a consequence, the main design criteria used for the CPW case study included:

- On-demand availability for all water users
- The same number of delivery point nodes (305)
- Peak Rate of supply at farm delivery point equivalent to 0.6 l/s/ha
- Annual water use 625 mm
- Minimum supply pressure at full demand 5 m

For the ALIS case study, the design criteria for the piped supply were:

- On-demand availability for all water users
- The same number of farms serviced (27)
- Peak Rate of supply at farm delivery point equivalent to 0.49 l/s/ha
- Annual water use 625 mm
- Minimum supply pressure 42 m at all times

## *2.3 Distribution Layouts*

**Central Plains.** The CPW study area of 36,000 ha is 56% of the total scheme area of 64,000 ha. This relatively large sample size was selected to capture the range of topographic variability that exists across the full area, and to ensure that the findings could be reasonably applicable for the full area. The layout of the proposed CPW open channel distribution system is shown on Figure 1

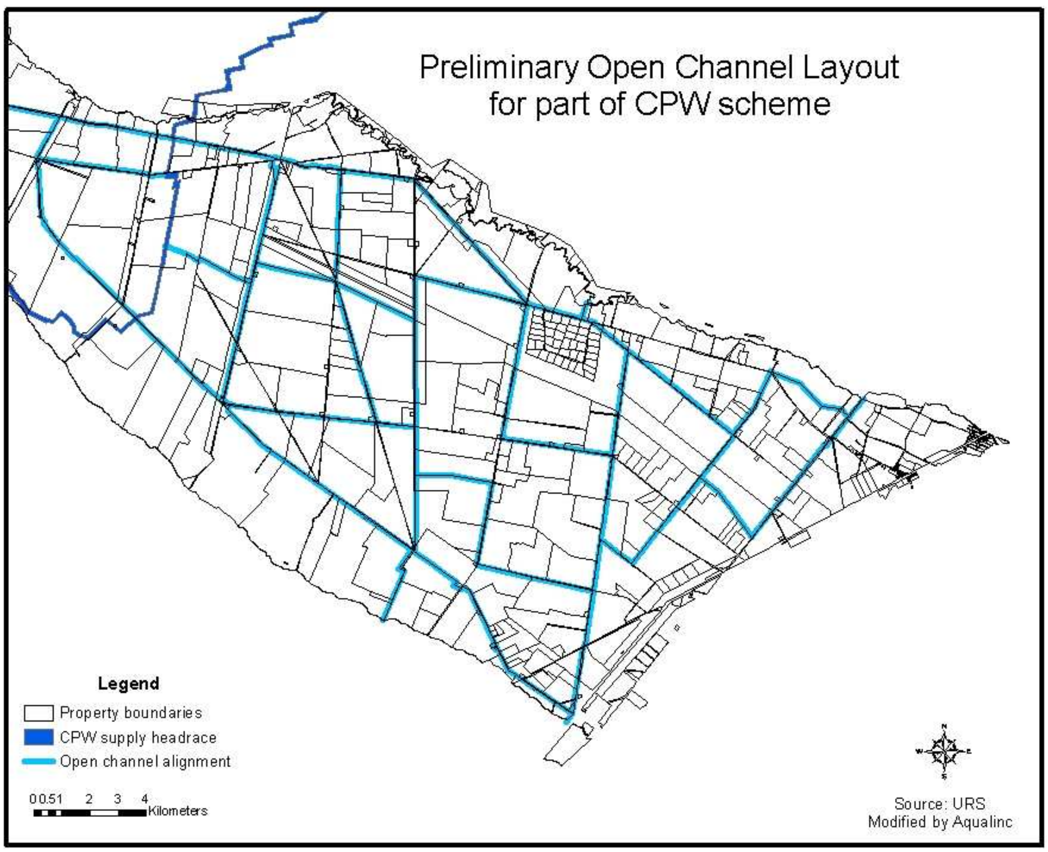


**Figure 1: Preliminary open channel layout for part of CPW scheme**

This layout is that adopted by the CPW consultants for the purpose of land designation and has been negotiated with the landholders to minimize disruption to farm operations. The discharges in each section of the channel system are shown, as provided by the CPW consultants. It will be noted that additional short pipe extensions had to be provided to supply each farm outlet and make the system comparable to the piped delivery system. In general terms, main supply channels follow roads, with the channel formation located within the property boundary of adjacent farmland.

The layout adopted for the proposed CPW piped distribution system is shown on Figure 2. This layout was chosen as optimum from a range of layouts investigated. It will be noted that the layout does not necessarily follow roads and delivery points are comparable to the open channel layout.

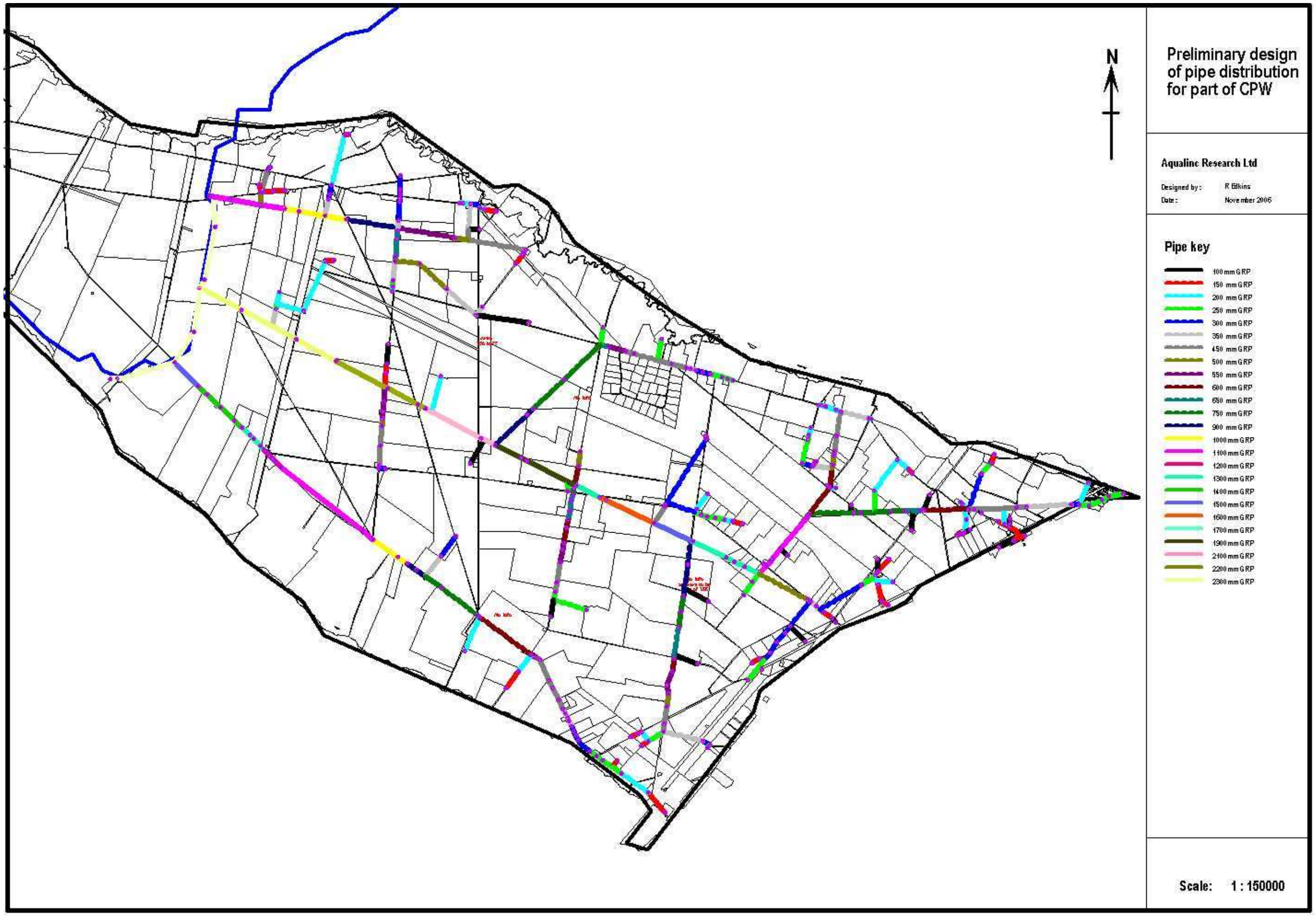


**Figure 2: CPW - proposed pipe layout**

**ALIS.** The area covered by the ALIS case study (4,084 ha) is shown on Figure 3. The existing lateral races – Laterals 1, 2 and 3 are shown as well as the chosen alternative piped system.

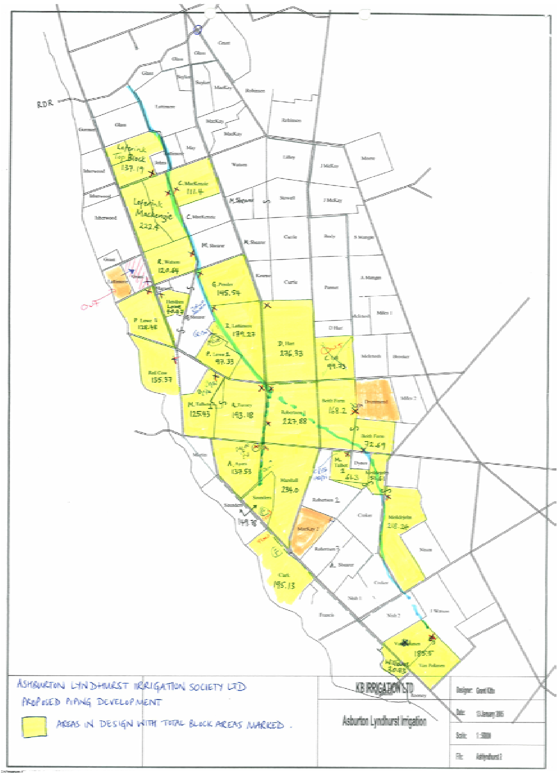


**Figure 3: Part of ALIS Scheme**

## *2.4 Capital Costs*

Capital costs are based on estimation of physical quantities, material costs and unit rates. Unit rates and material costs for items shown on the costing tables in Appendixes 2, 3 and 4. These are based on recent tenders and as-built costs for completed projects with similar items. The hydraulic design and estimates of work quantities and associated capital costs have been subjected to independent peer review by Beca Engineering Consultants, which generally confirmed the reasonableness of the rates used.

## *2.5 Operations and Maintenance Costs*

The estimation of operational costs includes the fixed and variable costs of the establishment needed to operate each scheme, based on experience with established open channel and piped schemes in NZ. Maintenance costs for each option are based on costs collated for similar open channel schemes and assumptions about the maintenance needs of the CPW scheme, benchmarked to other piped schemes.

## *2.6 Energy Costs*

**Central Plains** The design of both options assumes that on-farm pumping will be needed using variable speed pumping installations for the piped option and fixed duty pumps for the open channel option. The pipe scheme design has considered the trade off between the incremental capital costs of providing higher pressures at farm boundaries by reducing friction losses versus on-farm energy costs. Figure 2 shows a design based on delivering a minimum pressure of 5 m at farm turnouts under the piped system – in the CPW scheme assumptions, this is the most cost effective solution. Energy costs with the piped system will vary depending on farm location. Figure 4 shows the variation in supply pressures across the study area that indicates that the design minimum of 5 m is exceeded for a large number of turnouts for a good deal of the time in an average season. Energy costs for the open channel option assumes pumping from ground level. Estimates of average annual energy costs for each option are based on the average water requirements derived from a 30 year climatic sequence. Details are given in Appendix 2.

**ALIS**. The design of the ALIS piped system results in zero cost for energy, and account has been taken of the energy costs involved in some pumping from the open channel system.

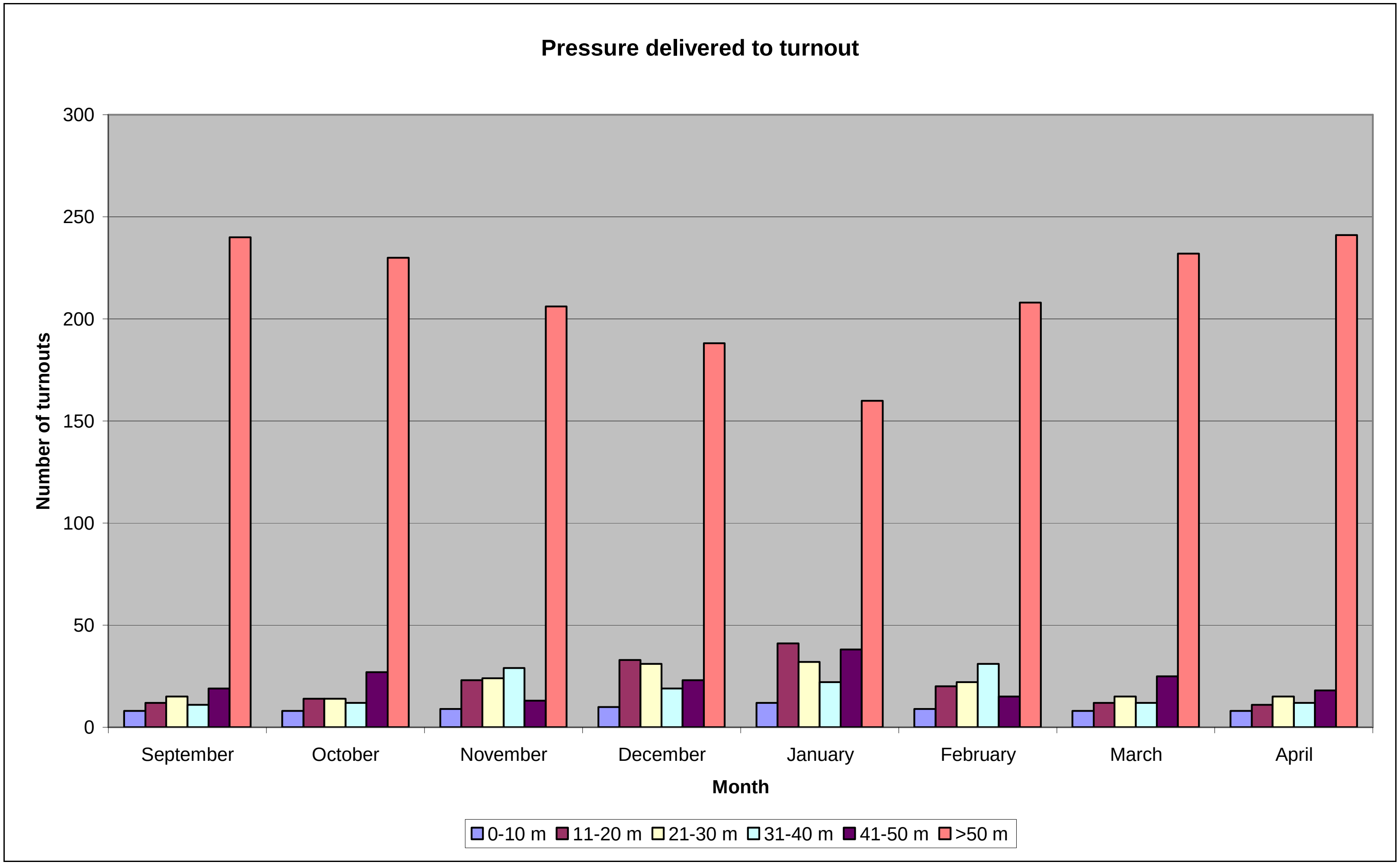


**Figure 4: Turnout pressure for different flow demands, for turnouts located lower within the scheme**

### *2.7 Benefits from Distribution Efficiency Differences*

**CPW and ALIS.** Losses from the piped distribution system will be minimal – no seepage or operational losses have been assumed. Based on CPW consultant estimates, the losses from the open channel system from these two causes have been estimated at 20%. Measured losses in Laterals 1, 2 and 3 of ALIS case study area are 20%.

The cost/benefit accommodation of these differences has been assessed by assuming that saved water has a market value and can be sold after scheme commissioning, as explained in more detail in Section 3 this report.

## 3.0 Economic Cost Comparisons of Pipe and Open Channel in Case Studies

The technical analyses and cost estimates of the detailed case studies are given in Appendixes 2, 3, 4 and 5; and the economic cost comparisons of the case studies are based on the generic methodology in Appendix 6.

The economic cost comparison between pipe and open-channel options follows the generic methodology, with the common assumptions applicable to each case study summarised below:

- All prices are in constant 2006 dollars;
- The analysis period adopted is 30 years;
- Base capital costs are "best estimates" and include commissioning costs but exclude physical contingencies[1];
- The options are compared in discounted cash flow framework over this period with real discount rates of 6, 8 and 10 percent; and
- Real electricity prices are assumed to rise by 1 percent annually over the next 10 years.

This generic framework is then applied to each case study as follows.

### *3.1 Central Plains Case Study*

The sub-area adopted in this case study is described in Section 2c, and covers a gross command area of 36,000 ha. The specific assumptions applicable to the economic analysis of this case study are as follows:

- Implementation extends over 5 years, with the first 2 years devoted to resource consenting and initial preparatory work, and the subsequent 3 years to civil work;
- Commissioning costs add 3 percent to capital costs and are spread over years 5 of the implementation period and into Year 6, the first year of operation;

[1] Physical contingencies would need to be included as part of detailed project costings.

- Resource consenting expenditure for the open channel option occurs over years 1 and 2 of the analysis period, and involves an investment of 5 percent of base capital costs spread equally over the 2 years– the piped option involves an expenditure of 85 percent of this amount;
- Legal costs for the open channel network are assumed at 4 percent of base capital costs, equally spread over Years 1 and 2 – expenditure for the piped system is at 40 percent of this amount;
- There are no additional infrastructure costs (such as upgrades to the electricity network) associated with either option;
- The open-channel system will require the canal footprint to be purchased;
- The pipe system will require easements to be established over the reticulation footprint, the costs of which are reflected in legal costs.
- The open channel network assumes the purchase of 280 ha of land for the canal footprint, and another 22 ha of land for other minor works, or a total of 302 ha. The pipe scheme assumes 164 ha of land for land easement, with no land purchase;
- The compensation price for land purchase is $15,000/ha.
- Operational costs for both systems are $16/ha;
- Pump R&M is assumed at 3 percent of capital cost;
- Pumps are replaced after 15 years assuming 3,000 operating hours per year. With the open channel system, all 305 pumps are replaced at year 15. With the pipe system, 57 turnouts do not require pumps. Of the remaining 248 turnouts, pump replacement is programmed between years 15 to 25 depending on average usage/load.
- System maintenance costs for the open channel system are $15/ha and for the pipe system $12/ha.; and
- Water "savings" with the piped system are assessed at 20 percent of the water that would be required at the headrace of the open-channel network. This water has a "value" of $4,600/ha and is "sold" in the 2 years following scheme commissioning.

The results of the analysis with these assumptions are shown in Table 1.

**Table 1: Central Plains - Open Channel vs Pipe**

| | **Present Value Cost ($ millions)** |
|---|---|
| Open Channel System | |
| 6% discount rate | 162 |
| 8% discount rate | 132 |
| 10% discount rate | 110 |
| Piped Distribution System | |
| 6% discount rate | 118 |
| 8% discount rate | 102 |
| 10% discount rate | 90 |

This analysis indicates that the piped distribution system holds promise to be a cheaper option than the open-channel system, when evaluated over a 30 year analysis period. Although the piped system is about twice as expensive in terms of base capital costs ($123 million vs. $64 million), the lower operations costs with the piped system because of the pressurised water delivery reducing on-farm pumping costs, together with the value of the water savings generated from the piped system, result in a lower-cost alternative when viewed over the longer term.

In terms of sensitivity analysis, this result is robust across all three discount rates. In addition, sensitivity testing indicates that:

- Should there be no real increase in the price of electricity over the analysis period, there is negligible change to the results because the "value" of these savings do not start to occur until after Year 6 and then only escalate at 1 percent annually for 4 years;
- Should the value of the water "savings" be negligible, then the two options become comparable in present value cost terms at the higher discount rates (8 and 10 percent);
- Should capex costs increase by 20 percent, the piped option still remains the preferred option in terms of the present value of comparative costs; and
- If pump operating costs increase by 20 percent, there is only a small change to the results, and the comparison remains similar.

### *3.2 ALIS Case Study*

The sub-area adopted in this case study is described in Appendix 4, and covers a gross command area of 4,083 ha and supplies water to 3,200 ha. The specific assumptions applicable to the economic analysis of this case study are as follows:

- Implementation extends over 4 years, with the first year devoted to resource consenting and initial preparatory work, the subsequent year to preparatory work followed by two years of civil work (Years 3 and 4);
- Commissioning costs add 3 percent to capital costs and are spread over years 4 of the implementation period and into Year 5, the first year of operation;
- Resource consenting expenditure for the piped system occurs in year 1 of the analysis period, and involves an investment of 2 percent of base capital costs;
- Legal costs for the piped network are assumed at 1 percent of base capital costs, equally spread over Years 1 and 2;
- There are no additional infrastructure costs (such as upgrades to the electricity network);
- The pipe system will require easements to be established over the reticulation footprint, the costs of which are reflected in legal costs;
- The pipe scheme assumes a network layout involving land easement, with no land purchase;
- The piped system will "release" for sale that area of land which currently forms the footprint of the open-channel network– it is assumed that 30 ha of this land will be sold in Year 5 at $15,000/ha.;
- Operational costs for both systems are $16/ha (in other words, no operational costs savings are assumed);

- Pump R&M is assumed at 3 percent of capital cost;
- Pumps are replaced after 15 years assuming 3,000 operating hours per year. With the open channel system, all 27 pumps are replaced at year 15. With the pipe system, 8 turnouts do not require pumps. Of the remaining 19 turnouts, pump replacement is programmed between years 15 to 25 depending on average usage/load.
- System maintenance costs for the open channel system are $15/ha and for the pipe system $12/ha (in other words, the pipe system has a maintenance cost saving of $3/ha.); and
- Water "savings" with the piped system are assessed at 20 percent of the water that would be required at the headrace of the open-channel network. This water has a "value" of $4,600/ha and is "sold" in the 2 years following scheme commissioning.

The results of the analysis with these assumptions are shown in Table 2.

**Table 2: ALIS - Replacing Open Channel with Pipe Reticulation**

| | **Present Value Cost ($ millions)** |
|---|---|
| Piped Reticulation System | |
| 6% discount rate | 4.5 |
| 8% discount rate | 5.0 |
| 10% discount rate | 5.3 |

This analysis indicates that the piped distribution system is likely to be more expensive than the open-channel system it replaces when evaluated over a 30 year analysis period. The capital costs of the piped system are such that they cannot be offset by the savings in operations costs (reduced on-farm pumping costs), together with the value of the water savings generated from the piped system.

In terms of sensitivity analysis, this result is robust across all three discount rates. Using the 8 percent discount rate as a comparative benchmark, the base case PV of cost for retrofitting is $5M. If capex is reduced by 20 percent, this falls to $2.9M and if capex falls by 40 percent, the PV of cost falls to $0.8M, leading to the conclusion that the result is most sensitive to capex. If water sales revenue increase by 20 percent, the PV of cost in the base case falls from $5M to $4.7M. In the case where opex cost savings are increased by 20 percent, the PV of the cost falls to $4.5M.

Assessing the risk appetite that developers of a scheme are willing to accept can significantly affect the price paid for construction; operation and maintenance costs; and the replacement period between parts of the scheme infrastructure as it wears out. Risk is not discussed in detail in this report, but an inherent assumption is made that developers will assess it at all levels and for all components of a scheme whether specifically, or by intuition in the decision making process.

To assess the influence of risk and decision making, the ALIS case study was subject to a second phase of pricing to determine if capital cost could be reduced by altering risk assumptions. The focus was to reduce the costs as originally designed. The following lists altered assumptions for assessing the revised costs.

- There is minimal design and a larger portion of 'contractor' design is utilized.
- A small contractor is utilized
- A simple form of contract is used with risk sharing accepted with owners.

- The project is not tendered
- There is a significant portion of the project management undertaken by the scheme developers and the contractor.
- Cheaper pipe materials are utilized, PE in place of FRP.
- Fencing and infilling of the canal for example are not undertaken.

The construction price calculated was approximately $8,500,000m or $2,656/ha. The price was cross checked and confirmed by a contractor. The revised price is approximately 35% lower than that developed in earlier design, and alters the NPV analysis accordingly. If this capex is transferred across to the economic analysis summarised above, the assessed PV of cost for the retrofitting option decreases from $5M in the base case (at a discount rate of 8 percent), to $1.6 M.

## *3.3 Comparison of Results*

It is informative to list some of the reasons why a piped reticulation system is apparently more cost-effective in the Central Plains scenario, whereas retrofitting a piped system into the ALIS may not be as cost effective. In this regard:

- The piped network for the CP scheme involves a base capital cost of around $3,400/ha compared with that for the ALIS at just under $4,100/ha. This is a result of the different layouts (with ALIS being a longer, narrower layout with only some of the properties supplied) and the ALIS design criteria to supply at a minimum head of 42m. Layout, however, appears to have a comparatively dominant impact on scheme cost.
- The CP scheme has higher on-farm pumping operating cost savings for pipe versus open channel than ALIS because: (a) ALIS has a lower system capacity, with less flow being supplied to each property; (b) ALIS has a lower target pressure to be supplied; and (c) ALIS has lower electricity costs.
- The piped network for the CP generates on-farm pump operating cost savings compared with the open channel option of around $160/ha compared with the ALIS of just under $100/ha. The CP figure results from relatively high energy cost values for both options subtracted, whereas the ALIS figure results from a modest energy cost of the limited pumping from races at present, to the piped option where energy costs are zero, because of the high delivery pressures.

## *3.4 Additional Considerations*

It is emphasised that the economic analysis above is only part of the comparative evaluation – other aspects (both perceived benefits and costs, but parameters which cannot be quantified in monetary terms), need to be included in any comprehensive comparison. The extent to which each of these issues will apply, and the weight given to each, will vary with individual circumstances, but the following table lists some of the factors that should be canvassed in any comprehensive comparative evaluation of the options. Individual circumstances may also generate the need for additional matters to be considered which are not listed below.

**Table 3: Additional Considerations**

| System | Additional Potential Comparative Benefits |
|---|---|
| | |
| Open Channel Reticulation | Allows augmentation of lowland streams (although piped schemes can allow direct augmentation) |
| | Provides additional groundwater resource for potential abstraction |
| | Provides additional groundwater for dilution of leachates |
| | Creates potential wildlife habitats |
| | Provides more equitable on-farm pumping costs across the command |
| | Provides opportunity to collect and utilise by-wash |
| | Easier to expand in the future |
| | Creates opportunity for amenity and recreation benefits on waterways |
| | Provides for easier implementation through the improved “bankability” which attaches to lower capex. |
| | |
| Piped Reticulation | Reduces potential for water mixing with cultural and bio security implications |
| | Reduces need for rostered water delivery systems |
| | Provides pressurized water for fire-fighting |
| | Reduces access disruption to farm operations from channel bridges, culverts and fences |
| | Increases land use flexibility without channels dissecting paddocks |
| | Provides higher water quality at farm turnout |
| | Reduces need to discharge excess flows after stoppages |
| | Easier to measure scheme flows |
| | Reduces issues in health and safety |
| | Increases scheme security |
| | Reduces risk of water contaminants |
| | Less exposure to real price rises in energy costs |
| | More socially acceptable to wider community |
| | Reduces visual impacts |
| | Provides potential potable water supply |
| | Is perceived to be a more “sustainable” use of resources |
| | |

Many of these parameters derive from comparisons of both options from social, cultural and/or environmental perspectives, which were issues canvassed during the study through group workshops. The report of this aspect of the investigation is included in Appendix 8, and summarised below.

## 4.0 Social, Cultural and Environmental Issues

An objective of the project was to gain a better understanding, from rural community people, farmers and stakeholders, of the social, environmental and cultural issues both for and against piped and open channel distribution systems for large-scale water enhancement projects. The approach used was to run two small group workshops at Hororata, in the heart of the Central Plains Water case study area.

Participants of both workshops readily identified pros and cons of both distribution systems, with consistently the same issues expressed at both workshops. The majority of issues presented were either for pipes or against open channels, and were predominantly the antithesis of each other. The results represent a generic position of the attitudes of the rural communities to the choice of options, and these are summarized in Annex 1. They are likely to apply, in general, in other situations.

**Pipes Positives:**
The main points in support of piped systems includes aspects of land utilization; energy savings; less disruption to current activities; safety; environmental; aesthetics; flexibility; water quality; and community acceptance, consenting ease.

**Pipes Negative:**
The negative aspects of the piped alternative included: the high upfront cost; higher earthquake risk and possible disruption to farming operations during installation; and where pipes were replacing open channels was the issue of loss of environmental habitat and biodiversity.

**Open Channel Positive:**
By contrast, benefits for open channels included: lower capital cost; potential recharge of aquifers[2]; potential to generate electricity (which was also identified as a piping opportunity); warmer water and perceived easier future expansion.

**Open Channels Negative:**
The perceptions about the negative aspects of open channel distribution include: land loss; poor access; poor safety; community disruption during construction; less harmonious community process especially land purchases from unwilling sellers; high cost of land purchase; water loss through leakage and evaporation; poorer water quality and vulnerability to pollution; contamination and sabotage; higher maintenance; no water in winter for community use; and dry channels in winter.

A significant outcome of the workshops was that the majority of the piped distribution benefits could not be classified as just social, cultural or environmental benefits, but did in fact cross several these classifications and in many cases offered economic benefits as well. The overall conclusion was that piped distribution systems were, in general assessment, more sustainable.

## 5.0 Summary and Conclusions

This investigation of piped and open channel options for large scale irrigation water has as its objective the development of a generic methodology that can be used to capture the main features of each option for decision making purposes.

The study used two case studies to inform the recommendations of the generic methodology: (i) a “greenfields” proposal for a sub-area of the Central Plains Scheme; and (ii) a retrofitting proposal to convert an existing open channel distribution system in the Ashburton Lyndhurst Irrigation Scheme.

[2] The potential positives of a piped system in regard to beneficial recharge were raised at the review meeting – the point being that seepage losses may not be entirely negative in certain situations.

The results of the CPW investigation show that the capital cost of the piped option is roughly double that for a comparable open channel system. Once all of the associated costs and benefits are included, however, it is clear that the NPV of the piped option is considerably more attractive. The implications for the scheme are that: (i) the benefits that make the piped option a more attractive long term option are largely captured by the water users in terms cost savings; (ii) the social and environmental benefits associated with the piped option are of interest to the general public and the communities affected by the scheme development; and (iii) the scheme developers/financiers will need to devise ways of reflecting the benefits of the piped option in developing a financial structure of the development that may support the more expensive piped option.

The economic comparison results of the ALIS retrofitting proposal indicates less benefits to the piped option[3]. The reasons for this result were assessed to be: (i) the low energy cost savings involved, because of the low level of current energy costs; (ii) the relatively larger ratio of piped cost/area served, a function of the layout; and (iii) assumption of less than 100 percent uptake in the initial stages. The attitude of the retrofitting proponents in supporting the proposals was that the change to a gravity piped system would remove the risk and uncertainty perceived of higher future energy costs and the likelihood of full uptake in the future.

In regard to the non-economic issues – social, environmental and cultural - it is clear that rural communities see many long-term benefits in adopting gravity piped distribution technology. The main problem in acting on this attitude was seen to be the higher first cost of the piped option and the financing difficulties that this presents to a sub-section of the beneficiary community in implementing the piped option. The case was made for involvement and support from the wider community to facilitate the implementation of developments that were clearly seen to have long term benefits to the community at large.

A generic approach to the comparison is supported by the material in Appendix 7, which records the general understandings gained during the course of this investigation and the experience of the study team. The main findings that apply to the generic issues are summarized in Annex 1. In addition, a "how to" approach is illustrated in the detailed reports of the two case studies in Appendixes 2, 3, 4 and 5.

[3] This assessment is not as conclusive if a lower cost and less robust design solution is adopted.

# Annex 1: Generic Findings Derived from the Case Studies

Experience gained from the detailed case studies has informed the proposed generic approaches reported in Appendix 7 – on technical aspects, and Appendix 6 – on economic cost comparison methodology. The main findings that have migrated to the generic appendixes from the case studies are summarized below:

## 1 Technical Pipes

As a general comment, the design criteria for the two options should be specifically identified to ensure that the levels of service are comparable

- Optimization of the piped layout is important as there will be a number of combinations of pipe sizes/delivery pressures feasible, each with unique capital and energy costs. The aim should be to select the option with the lowest NPV at the interest rate selected.
- The detail of turnout plumbing is dependent on turnout function, and this needs to be specifically addressed for each situation.
- The protection of the off-farm piped system and on-farm piped systems is a key requirement. It is better to design the off-farm system to cope with the operating pressures, including transients, without the need for pressure regulation within the system; and to protect the on-farm system with pressure control at the turnouts.
- Pressurized pipeline locations are extremely flexible and cause little longer term disruption, and are more acceptable to the community.
- Pipe material, design life and sensitivity to changing hydraulic properties need to be considered.
- Robust comparisons of energy cost differences should take account of the variable seasonal water requirements over a long period, and not be based on peak demands.
- Contour information used in hydraulic design of piped networks needs to be appropriate to the topography.
- Optimization is best done through use of computerized design software, such as Irricad™ .
- When supply points are subject to varying delivery pressure, variable speed pumping units are needed to ensure high pumping efficiencies.
- Pressurized pipe systems have the potential to provide 365 day firefighting facilities. If this is an important issue, looped or interconnected layouts may provide a higher level of security.
- On larger schemes, peak design demand should be set at between 70 and 80% of the theoretical peak demand[4].
- The case study experiences suggest that designing for higher velocities and hence lower delivery pressures is more than offset by increased pumped capital cost, without having to account for decreased energy use – therefore keeping velocities below 3 m/s is an economic plus and also reduces issues with pressure transients.

[4] The work reported herein was based on meeting 100% of theoretical peak demand.

# 2 Technical Open Channels

- Canal scheme design is typically unique to the location and flow requirements, and unit costs are not easily transferred from one scheme to another.
- Local geology, topography and intake locations significantly alter the infrastructure design.
- In the NZ situation land gradients on irrigated land tend to be steeper than in other places. Open channel distribution systems running downslope will require either (a) provision of head loss structures or (b) protection of the canal prism from high velocities. The choice has important cost and operational implications.
- Modern open channel distribution systems are capable of operating close to on-demand and with low operational losses to bywash spillage, using available downstream control technology. Any valid comparison of piped and open channel systems should require a similar same level of service delivery and performance.
- The criteria adopted for acceptable water losses in open channels are an important consideration for developers and the appropriate Resource Consenting authority. Where seepage targets are set without regard to the available soil types and construction materials canal lining may become prohibitively expensive or possibly unfeasible from a technical viewpoint. Lining costs are a large portion of canal costs.
- Contractors and equipment for canal scheme construction are readily available and competitive prices can be obtained for construction.
- For larger canal schemes it may be appropriate to pipe smaller sub areas of the scheme rather than constructing tertiary canal systems.
- Water management of canal schemes is often more wasteful than pipe schemes. Utilising modern control systems and equipment such as automated gates for a new scheme will provide significantly improved water usages than a manually controlled system.

# 3 Estimates of Capital Costs

Appendix 5 provides useful guidance for the estimation of capital costs to be used in the economic cost comparison of the pipe and open channel options. Capital cost is a major issue in selecting a preferred option especially for scheme developers and financiers. Some of the major findings from the experience gained in the case studies and other similar projects include:

**General**

- Suppliers and contractors are often willing to assist with pricing components of projects.
- The accuracy of cost estimation and reliance put on values should be reflective of the level of investigation and design.
- In early stage investigations scheme costs are rarely over-estimated. Often costs are underestimated with hidden costs and requirements only considered at later stages. A number of unexpected costs often become exposed in detailed design.
- Effort to complete several design iterations is recommended to optimise scheme designs as significant savings can be made with clever designs.

**Related to Pipes**

- Installed costs of large diameter pipes are generally similar. Less expensive pipe types often come with specialized installation systems that increase cost
- Pipe cost may represent up to 60% of total capital cost, so cost estimates are less dependent on specific scheme circumstances.
- Pipe sizes less than 600 mm can often utilize all material types. Above 600 mm the range of materials is more limited including supplier choice.
- For schemes with reasonable topographic variation a significant proportion of total cost will be for bends and anchor blocks.
- The case study spreadsheets were developed for gravity water supply at the intake. Pump schemes may alter pipe designs based on transient effects and the velocity versus friction loss design of the pipe.
- Contractors for pipe scheme construction are limited when compared to canal construction because of the specialist skills required, such as ticketed welding or installation techniques.

**Related to Open Channels**

- Canal scheme design is typically unique to the location and flow requirements and unit costs are not easily transferred from one scheme to another.
- Local geology, topography and intake locations significantly alter the infrastructure design and costs, and hence there is more uncertainty in cost estimates.
- The acceptance criteria for water loss as a risk by developers or set by consents significantly affects canal lining designs and costs if required. Lining costs are a large portion of canal costs.
- Contractors and equipment for canal scheme construction are readily available and cost competitive prices can be obtained for construction.
- For larger canal schemes it may be appropriate to pipe sub areas rather than construct secondary canal networks.

# 4 Economic Cost Comparison.

The generic approach for economic cost comparisons is provided in Appendix 6, focusing on two situations: (i) a new "greenfields" scheme proposal; and (ii) retrofitting an existing open channel distribution system with pipes. The following items need to be considered in the economic analysis of either situation.

**Capital Cost.**

Appendix 5 on cost estimation details the itemised capital costs required for estimating open channel and piped reticulation networks. Pre-construction costs will also need to be included, covering such items as feasibility studies through to final design, contract preparation and tendering, liaison with stakeholders, resource consent and building consent costs, legal fees, etc. Aspects of cost often overlooked include costs for:

- easements – different for pipes and open channels
- private disruption to access– may require compensation in open channel situations regardless of culverts and bridges
- land purchase
- additional costs associated disruption/upgrading to public infrastructure – roading, power, water supply

**Operational Costs**
Each system will also have associated operations (covering system operation and control) and maintenance costs – regular maintenance (say annually), periodic maintenance (say once every five years), and extraordinary maintenance (relating to response to extraordinary events such as major floods, power outages, or earthquakes). Additional items that will need to be addressed for each option include:

- on-farm pumping costs
- water savings and how these are to be valued
- on-farm irrigation management if different levels of service are involved
- improved water quality – reduction in potential for contamination and associated costs
- management of bywash flows
- public safety
- environmental externalities
- increased fire fighting resources.

# 5 Social, Cultural and Economic Considerations

There is a consistent perception amongst rural communities that piped distribution is a more "sustainable" option than a network of open channels. This perception seems to be based on a mixture of community aspirations and concerns that are difficult to unbundle into social, cultural and environmental categories. It is important that investigations of community views be based on detailed understandings of the technical proposals of possible distribution options. The level of detail of scheme proposals needed to assure this understanding was not available for the case studies, and the results should be treated accordingly.

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# APPENDIX 1
# LITERATURE SEARCH ON PIPES AND OPEN CHANNEL COMPARISONS FOR LARGE SCHEMES

## Contents

# LITERATURE SEARCH ON PIPES AND OPEN CHANNEL COMPARISONS FOR LARGE SCHEMES

## 1.0 Background

The agreed extension of project SFF 05-177 deals with the development of a generic methodology to allow a robust comparison of open channel and piped distribution systems for large scale irrigation schemes, in the NZ context. Milestone 1a of the extension project is a report of an international literature search for investigations of the pros and cons of open channel and piped systems for large scale irrigation flows. This work was undertaken as a detailed web based search of international literature and personal email and telephone contacts with various organizations and persons involved in open channel to piped conversions, and experienced engineering consultants involved in projects where large diameter pipes have been used.

## 2.0 Results

### *2.1 Web Based Search*

The web based search did not reveal any reports where the comprehensive comparison of open channels and pipes was specifically referred to. This is not surprising in that decisions to make conversions have normally been made on the basis of political or environmental imperatives.

Enquiries made of professionals in NZ, Australia and in overseas jurisdictions have confirmed this result – apparently the conversion from existing open channels to piped systems have been justified from a narrower viewpoint than is needed in the NZ context, as exemplified by the conversions undertaken and in progress and underway in Australia, Turkey and Malaysia.[1]

[1] Lars Kamerling, Amiantit, has made extensive enquiries amongst clients and has not encountered any formal open channel/piped conversion analyses.

## *2.2 Engineering Literature*

Economic aspects are one of the criteria of relevance to an assessment of relative merit. The two economic variables are initial and on going costs. The engineering handbooks and relevant texts contain engineering economic approaches to the selection of the most economic pipe type, in situations where the pipe options are all possible on technical grounds. Most commonly, the procedure involves a comparison of capital and annual costs. Annual costs of replacement are normally generated by estimating salvage value of each pipe type at the end of an arbitrary service life and maintenance costs necessary to justify the salvage value used. This approach has some merit when comparing like with like in the design phase, but has little relation to actual costs likely to be incurred during the service life[2].

Contacts were made with NZ suppliers of different pipe types and with pipe users to establish realistic service life assumptions and these will be useful when detailed assessments and case studies are undertaken.

## *2.3 Australian Experiences*

Based on email contact and telephone discussions with the major water authorities in Victoria and NSW, and the large private water supply and irrigation companies in these States, the two main reasons for conversion of open channels to pipes given were: a) water savings in situations where losses from open channels from seepage, evaporation and operation were considered to be unacceptable in areas of water shortage – an economic issue; and b) where environmental restoration was a key objective – to reduce seepage in order to lower groundwater levels in saline areas and return water to surface water bodies in order to restore ecosystem health. In such cases, the conversion decision was taken, and the analysis thereafter focused on choice of pipe material for relative longevity, ease of maintenance and reduced risk of physical damage from corrosion, abrasion or chemical degradation[3].

## *2.4 Malaysian and Turkish Experience*

The Government of Malaysia has been progressively replacing open channel irrigation supply systems to piped networks since the mid 1990s, because of the difficulties and costs in maintaining function of the open channels and water shortages in nationally important granary areas[4]. The reasons given by the Turkish Government for replacing recast concrete open channels distribution systems are based on operational inflexibility of open channels to meet modern water demands, water savings and interference of above ground infrastructure with farm transport systems.[5]

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[2] Don Preston, MWH, pers.comm.
[3] Discussion with the following: Gordon Henderson, Beca, Auckland; Lance Thompson, NZ Steelpipes, Auckland; Brett Tucker, Murrumbidgee Irrigation Ltd., Griffith, NSW; Doug Meill, Irrigators Council of NSW; John Martin, Grampions Wimmera Mallee Water Authority, Horsham, Victoria; Kim Alvarez, Dept. of Natural Resources, NSW; Peter Millington, consultant, Sydney.
[4] National Water Resources Study, Government of Malaysia, 2000
[5] Author worked on aspects of GAP Project in Turkey, 1998

### *2.5 New Zealand Experiences*

Most of the gravity-supplied surface irrigation schemes in NZ have traditionally relied on open channel distribution systems for a number of sensible reasons: adequate gradients to convey high flows by gravity in open channels; tradition; generous access to run-of-river flows; and reliance on border dyke on-farm irrigation methods. This was the most cost-effective and appropriate method for large schemes at the time, and there are some 250,000 ha of land developed under this system.

In recent years, environmental and market pressures have been building to reduce water losses and increase on-farm efficiency in the large community schemes. This has resulted in conversion of about 30 percent of the land under rostered surface flooding supply systems to pumped centre pivot irrigation systems with a better ability to meet short term water demands[6]. These conversions still rely upon open channel supplies to farm boundaries. This on-farm change mimics the parallel development of an additional 250,000 ha of private schemes, all dependent on pumping and piped reticulation.

There have been three small community irrigation schemes developed in NZ using piped reticulation – Keri Keri in the 1970s, Waimea East in the 1990s and Downlands under construction. In all cases open channels were contra-indicated by physical circumstances, so no comparisons were relevant. Large diameter piped reticulation options have been included in a number of irrigation proposals in recent times – Barrhill Chertsey and Central Plains – but no comprehensive analyses as proposed under this study were carried out[7].

There has therefore been no NZ experience with the use of extensive networks of large diameter piping under pressure to replace the function of the traditional open channels to bring water to farm supply points. This is changing, with plans afoot to investigate the replacement of two open channel lateral supply races in the Ashburton Lyndhurst scheme supplied by the Rangitata Diversion Race (RDR)[8]. The reasons given for the interest are reduced water losses and ability to supply water under gravity pressure thus reducing electrical energy use.

Large diameter steel pipes have been used in NZ as penstocks in Hydro Electric Power schemes for at least 40 years; and city water supplies have long relied upon a variety of medium sized piped reticulation systems – based on steel, asbestos cement and PVC mains. Newer piped products based on HDPE (high density polyethylene) and FRP (fibre reinforced polymer pipes) are being used to replace older mains, but the service life experience of these pipes is limited.

## 3.0 Findings and Conclusions

No formal assessment methodologies were found in the international experience that address the special features and issues of the NZ situation related to open channel and piped reticulation options in large scale water enhancement schemes.

[6] Craig McKenzie, farmer, ALIS pers.comm.
[7] NPV estimates in Barrhill Chertsey carried out by Aqualinc Research Ltd found that the NPV of open channel options and piped alternatives were similar, but the investigations were not exhaustive.
[8] Craig McKenzie, farmer, ALIS pers.comm.

The reason for the lack of similar assessments as proposed in this project has become clearer. Very few countries possess the unique features of the NZ situation – relatively steep gradients from water source to use point, giving the prospects of gravity pressure supply in pipes, and the ability to access source water at higher elevations.

The rationale for conversions in overseas jurisdictions tends to be dominated by political imperatives to gain water savings and environmental benefits; and in some developing countries, by problems with maintaining function of the open channel systems over time.

It was concluded from this survey that it is necessary to develop methodologies that are specific to the NZ circumstances if a robust assessment of the pros and cons of piped and open channel distribution options is to be possible.

# APPENDIX 2
# CPW CASE STUDY PIPED OPTION

## Contents

# CPW CASE STUDY PIPED OPTION

## 1.0 Introduction

### *1.1 Background*

A case study on the preliminary design and costing of a piped and open channel distribution system was completed for part of the Central Plains Water (CPW) area. These designs and costing were to provide the basis for establishing a generic method for comparing the pros and cons of large scale open channel and pipe distribution systems, by using the case study investigation to surface the main generic issues.

The CPW case study is also of interest to the Central Plains Water Ltd (CPWL), the entity promoting the CPW scheme, because of the widespread attention being given to the choice of a water distribution option by the CPWL shareholders. CPWL has contributed to the funding of this study.

A piped design option of a sub-area of the CPW scheme proposals was completed on the area of land located between the Rakaia and Selwyn River below the proposed CPW headrace to the Main South Road (SH1).

The detailed description of the design process for the piped option is a blueprint of the process that should be followed in similar investigations. The design process needs to address the following issues at the design criteria stage and then into detailed feasibility design:

- Setting the Design Criteria:
- Area to be served
- System Capacity
- Water Source Issues
- Topographic Issues
- On Farm Delivery Characteristics
- Pressure Control
- Layout Options and basis of optimization
- Turnouts
- Pipe Material
- Role of on-farm pumping
- Estimation of capital and annual costs

# 2.0 Design Details

URS[1] provided a plan showing the following details of the CPW scheme (refer to Figure 1):

- Location of CPW headrace
- Boundary of the total proposed irrigated area (relevant to this study)
- Property boundaries and property area
- Contour details (10 m contours)
- Proposed open channel layout

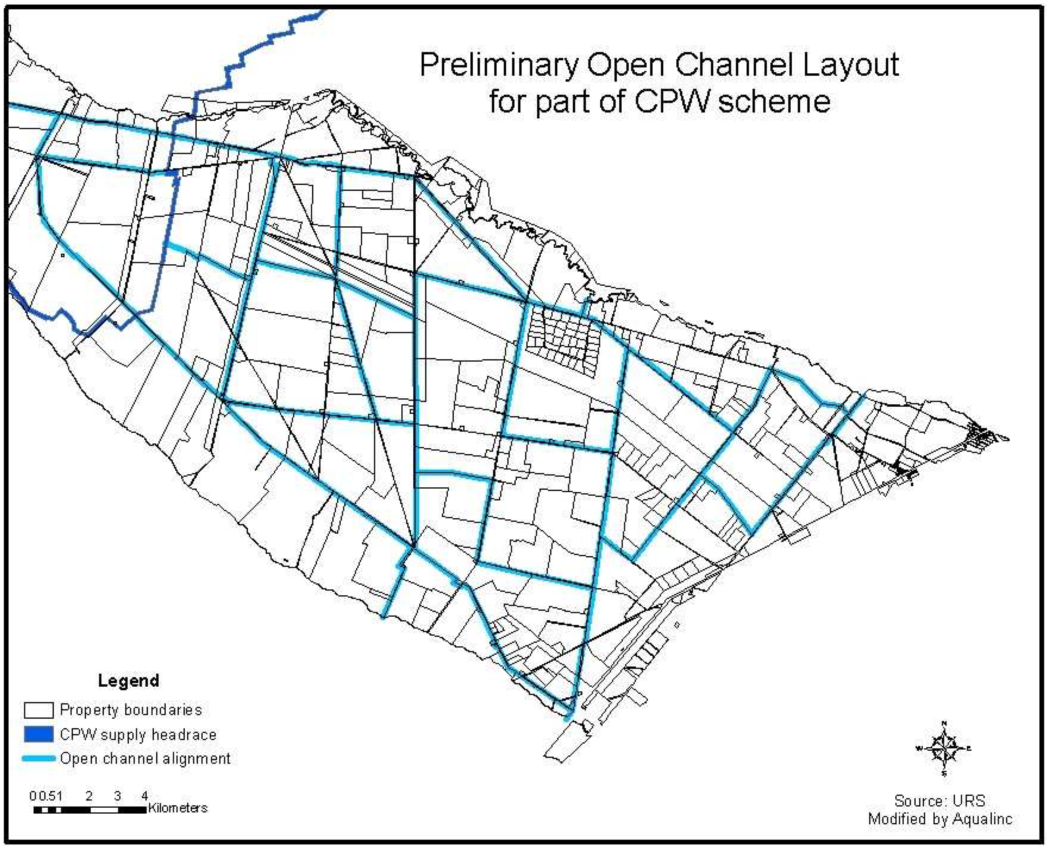



**Figure 1: Preliminary open channel layout for part of CPW scheme**

Water is to be abstracted from the CPW headrace, and will be delivered to the proposed irrigable area via a pipe network or open channel. The water will be delivered to each property using an off-take point (turnout).

## *2.1 Irrigated Area*

The total area to be irrigated in the case study sub-area is approximately 36,000 ha or some 60% of the total area proposed for the CPW scheme. Within this area, there are 305 turnouts to deliver water to each property. Some turnouts will deliver water to more than one property. There are 133 properties with turnout flow requirements of less than 1 l/s. These

[11] URS is the technical consultant to CPWL.

turnouts account for less than 1% of the total flow and are not included within the irrigated area.

## 2.2 System Capacity

The system capacity has been based on a delivering a flow of 0.6 l/s/ha[2] to each property. The total flow to supply an area of 36,000 ha is therefore 21.6 $m^3$/s.

The design is to be capable of supplying water to each property 'on demand' at all times[3].

## 2.3 Water Source

The water source is from the CPW headrace and thus provides flexibility in abstraction points, including the possibility of multiple off-takes.

## 2.4 Elevations

The highest elevation at the CPW headrace is at 240 m amsl and the lowest elevation is at the Main South Road at 63 m amsl.

The contour information as supplied by URS has been used. It is considered appropriate to use 10 m contours as interpolation between these contours gives a reasonable estimation of the lie of the land between the contours.

## 2.5 On Farm Delivery Pressures

The elevation change over the length of the pipe network provides additional pressure within the scheme, which means that properties can be delivered with water under pressure. This additional pressure in the system also enables smaller diameter pipes to be selected, as the elevation gain largely offsets the additional friction losses within the smaller diameter pipes. However, this will increase on farm pumping and a balance between reducing pipe capital costs and on farm pumping costs needs to be reached.

The approach taken was to minimise pipe diameters while maintaining a minimum delivered pressure to the turnout under full demand. In practice, due to the diversity of land use and management practices, it is anticipated that the scheme will only operate under full flow demand for short periods of time. For most of the time, particularly at the shoulders of the season, the flow demand will be less than 100% and at these times pressures delivered to the turnout will be higher, thus reducing pumping requirements. Many of the turnouts may not require pumping at all. The trade-off with this approach is that slightly more on-farm pumping is likely to be required than if the pipe diameters were selected based on a lower velocity. Therefore it is important to consider both capital and operational costs when considering the final costs of the scheme.

### 2.5.1 Turnout Delivery Pressure

A minimum pressure of 5 m was to be supplied to all turnouts under full flow conditions. This is to minimise issues with pump priming and negative pipeline pressures.

At the top of the scheme it has not been possible to achieve a minimum pressure of 5 m under gravity supply for some of the turnouts.

[2] This supply rate is adequate for irrigated pasture in the study area.
[3] On-demand operation is a basic criterion for both the open channel and piped options.

## *2.6 Pressure Control*

Due to the significant elevation change throughout the network the scheme may be subjected to high static pressures. In the CPW case, static pressure will be higher than dynamic pressure and was the main focus regarding pressure control. Options for managing static and transient pressures include use of pressure control technology; in-pipe power generation to "burn-off" excess pressure; or use of piped material that is capable of withstanding pressure requirements with an adequate factor of safety.

The option selected for this design study was to design the distribution pipelines to withstand static pressures. Pressure control-on farm as part of the turnout was assumed, which enabled lower pressure class pipe to be used on-farm. Typically lower specification pipes and construction occurs on on-farm irrigation systems, therefore it is important to isolate the risk of high pressure from the network.

Transient pressures should be modelled at the pre-feasibility stage of any design, and other pressure control options explored[4].

## *2.7 Pipe Layout and Sizing*

The pipe layout and pipe sizing was based on minimising the capital cost of the distribution pipeline to deliver a minimum of 5 m pressure to the turnouts[5].

It was assumed that there were no pipe layout constraints, that the pipeline was not restricted to roads and property boundaries and that impact of existing services was not an issue.

## *2.8 Turnouts*

Turnouts from the scheme distribution system will require some or all of the following basic components:

- Pressure reducing valve and pressure relief valves to control excess pressures
- Flow control
- Flow meter

Because specific turnout locations have not been specified, they were placed on property boundaries so that lateral pipe lengths could be reduced.

## *2.9 Pipe Materials*

Although any pipe type could be considered, fibre reinforced pipe (FRP) has been used for the design, one of the reasons being it has the ability to withstand high pressures. Also, the risk of the pipe deteriorating with age is low, so that the pipe roughness is unlikely to increase, thus scheme performance should be maintained throughout the pipes life. Nominal diameters have been used within the design.

[4] The review meeting raised the issue that transient pressures may require higher rated pipe. Detailed transient analysis undertaken for a scheme with similar characteristics (Barrhill Chertsey in Mid Canterbury) showed that static cut-off pressures were critical.

[5] A number of combinations of pipe sizes were investigated and this design solution minimized NPV of capital and operating costs. This may be different in other circumstances.

## *2.10 On Farm Pumping*

Water is to be supplied to each turnout under pressure. However, due to friction losses or changes in elevation along the pipe network, a reduced amount of on-farm pumping may be required. To operate the on-farm irrigation system effectively, a minimum pressure of 50 m has been assumed. Where less than 50 m pressure is delivered under gravity, small on farm booster pumps will be required.

To aid in the assessment of on-farm pumping requirements, land use projections and monthly and seasonal irrigation demand estimates were scaled from irrigation demand modelling undertaken in the Ashburton region. This was the basis for the criteria used for determining the change in irrigation demand through the irrigation season and the operational costs for on-farm pumping.

Due the variation in pumping pressure and flow required throughout the season, pumps fitted with variable speed drives have been assumed.

### 2.10.1 Irrigation Demand

A water demand scenario for the Ashburton region was modelled in the Canterbury Strategic Water Study (2002), to determine average and peak monthly irrigation demand. A daily time series of potential irrigation demand was calculated in the Ashburton region using daily rainfall and climate data from June 1972 to May 2000 based on the land-use assumptions summarised in Table 1. Both the monthly peak flow demand and average monthly flow demand were calculated.

**Table 1: Assumed land-use for potentially irrigable land**

| Region | Dairying | Intensive Livestock and Dairy Support | Arable |
|---|---|---|---|
| Ashburton | 52 % | 30 % | 18 % |

To estimate the potential irrigation demand for the Rakaia/Selwyn scheme, the data from the Ashburton region has been scaled, based on the peak flow difference between the Ashburton and CPW, thus enabling the monthly flow demand to be calculated. The average flow demand as a percentage of the peak flow for each month is shown in Figure 2.

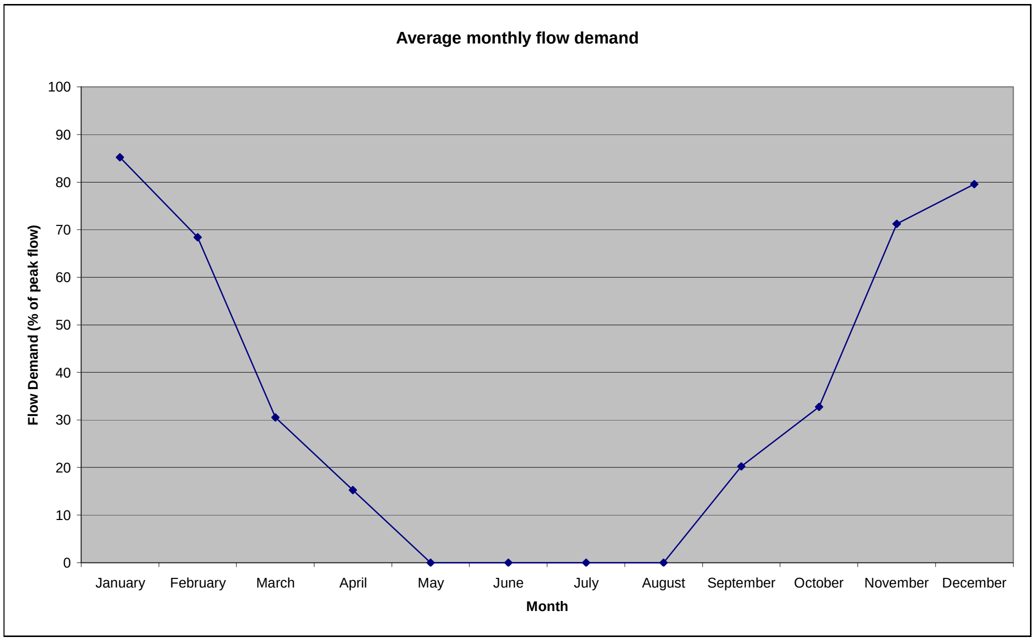



**Figure 2: Average monthly flow demand**

# 3.0 Hydraulic Design

The plans showing the property boundaries and scheme layout, supplied by URS, were imported into Irricad™ irrigation design software.

Firstly, the pipe layout was optimised based on reducing pipe capital cost.

Secondly, a detailed hydraulic analysis was completed, to finalise the pipe diameters of the network to ensure all design requirements and appropriate design limits were met.

Thirdly, based on the finalised pipe layout and pipe diameters, on-farm pumping costs were estimated.

Finally, an assessment on the trade-off between pipe capital cost and on-farm pumping was completed based on considering the NPV for the network.

## *3.1 Pipe Layout*

### 3.1.1 Design Options

During the pipe layout optimisation process, the pipe capital cost for one intake point from the race compared to multiple intake points was compared. Three main options were considered regarding the pipe layout, as follows:

- Option 1 – one intake from the CPW headrace with one main distribution pipeline taking the most direct route with lateral branches to supply the turnouts
- Option 2 – three intakes from the CPW headrace with three main pipelines taking the most direct route with lateral branches to supply the turnouts.
- Option 3 - three intakes from the CPW headrace with one main pipeline taking the most direct route with lateral branches to supply the turnouts. Small pipelines will deliver water to the turnouts at top of scheme.

For all pipe layout options the following method was followed.

### 3.1.2 Method

**Entering data into Irricad**
Based on the plans supplied by URS the following information was entered into Irricad™ irrigation design software:

- Scheme boundary
- CPW head race
- Property boundaries
- Contour information

All turnouts were entered into the modelling software based on supplying each property at the required flow rate determined from scheme system capacity (0.6 l/s/ha) multiplied by area of the property. Then the pipeline for Options 1, 2 and 3 were entered in, taking the most direct route as possible to minimise the length of larger diameter pipe. Lateral pipelines branching off from the main distribution pipe were used to supply the turnouts.

**Pipe layout optimisation**
To optimise the pipe layout, changes were made to the layout while comparing pipe capital costs to assess whether the revised layout was more cost effective.

To effectively compare capital costs between each scenario, a quick assessment of the pipe diameters required throughout the network for different layouts is required. The method needs to be repeatable and provide for a consistent and comparative approach for assessing the different layouts.

To quickly assess the pipe sizes for each pipe layout iteration, the pipe diameters throughout the entire network were sized based on a maximum velocity. The maximum velocity was selected so that a positive (essentially greater than 1 m) pressure was delivered to the majority of turnouts and to ensure that the pressure within the main distribution pipe was gaining down the network. This approach meant that typically only pipe diameters on the laterals needed to be adjusted to ensure all turnouts received positive pressure when finalising pipe diameters (see below). The maximum velocity was set to 3 m/s.

Cost savings were made by directing the flow from the main pipeline into smaller branch mains as high as possible in the system, thus allowing a smaller diameter main pipe to be selected. Generally, the cost saving gained by reducing the larger diameter pipe was more than offset by the cost in the increased length of smaller pipe.

Also, the lengths of laterals were reduced by relocating the turnouts. Turnouts were positioned as close as possible to the main delivery pipe to reduce the incidence of two pipes bordering one property. In some cases, this resulted in some turnouts being positioned near the bottom, rather than the top of the property.

## *3.2 Pipe Diameter*

Once the pipe layout was optimised, the pipe diameters were finalised.

Firstly, the turnouts were identified where the delivered pressure was less than the minimum pressure of 5 m. Then pressure loss was checked along the lateral pipes. Where small diameter pipes had high friction losses over a short distance (particularly at the ends of the lateral), these pipes were upsized. Following that, pipes along the lateral which had the highest velocity were upsized until the minimum of 5 m pressure was delivered to all turnouts on that lateral.

The velocity in all pipes was checked to ensure that they were within acceptable velocity limits to reduce the risk of water hammer. Also, static and dynamic pressures were assessed throughout the scheme selected pipe classes to ensure that the pipe pressure limits were not exceeded.

## *3.3 On Farm Pumping*

### 3.3.1 Pump Size

Using the final pipe layout and pipe diameter, the pressure delivered to each turnout at 100% flow demand, i.e. when all turnouts were operating, was determined. Based on a minimum pressure of 50 m to operate the on farm irrigation system, the turnouts that required on-farm pumping and the pump head required was identified.

Assuming a pump efficiency of 75% and a motor efficiency of 90%, the pump size required at each turnout was calculated.

Using pump capital costs (supplied by Flowserve) and electrics cost data (supplied by Nairn Electrical) a relationship between capital cost and pump size was derived for a variable speed drive pump, as follows.

Pump capital cost ($) = 571.5 x Pump size (kW) + 15,196

Based on this data, total pump costs were calculated.

### 3.3.2 Pump Energy Cost

To enable calculation of the seasonal pump energy cost, the pressure delivered to each turnout for the average monthly flow demand was modelled (described above). This allowed average monthly pumping requirements to be calculated.

The number of hours that the turnout would have been operating at maximum flow within that month has been calculated based on the flow demand. For each month within the irrigation season, the on-farm pumping requirement has been calculated and then combined to give total season pumping requirements.

Based on the following energy charges within the region (supplied by Meridian), the annual energy costs were calculated:

- Daily charge $2.82/day = $1029/yr
- Energy charge 0.13c/kWh
- Capacity charge 0.32c/kVA/day = $123/kW/year (assuming a power factor correction of 0.95)

# 4.0 Results

## *4.1 Pipe Layout*

During the pipe optimisation process, Option 2 was selected as the preferred option to be investigated further, because it was the lowest capital cost. The final pipe layout was a variant of Option 2 and 3 with three intakes from the CPW headrace. Two main pipelines with lateral branches supplied the majority of the irrigated area with small diameter pipes delivering water from the other intake to turnouts near the top/middle of the scheme. The final pipeline layout is shown Figure 3.

The greatest cost savings could be made when the route was not constrained to property boundaries and road corridors, which allowed the most direct pipeline route to be chosen. This reduced the length of larger diameter pipe, which is where the majority of the cost savings could be made. The flexibility in locating a piped water supply distribution system and the option of multiple intakes, also contributed to significant savings.

Once a main layout had been chosen, it was found that minor changes in the layout actually resulted in only small percentage changes the overall pipe capital cost. It was not considered necessary to perform numerous iterations for the purpose of the study.

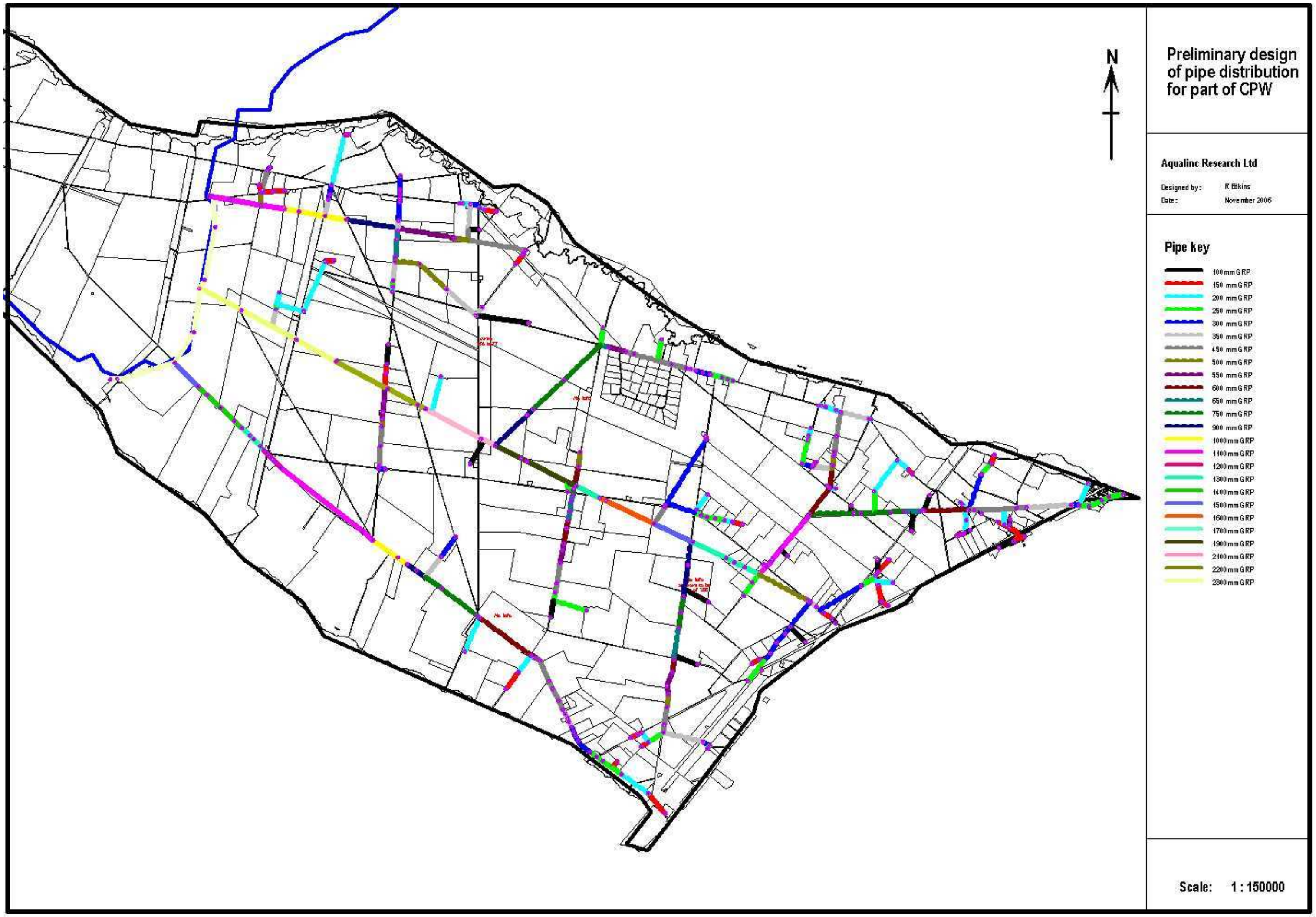



**Figure 3: CPW - proposed pipe layout**

## *4.2 Pipe Diameter*

The pipe diameter and pipe class was selected to meet velocity and pressure requirements.

The bill of materials for the preliminary pipe distribution network is summarised in Table 2.

**Table 2: Bill of materials – pipe lengths (m) for each class and diameter**

| | **Pipe Class** | | | | | **Total pipe length (m)** |
|---|---|---|---|---|---|---|
| **FRP** | **PN6** | **PN9** | **PN12** | **PN15** | **PN18** | |
| 100mm | 660 | 3,010 | 590 | 3,160 | 2,610 | 10,030 |
| 150mm | 2,110 | 860 | 800 | 3,810 | 3,620 | 11,200 |
| 200mm | 6,190 | 1,710 | 1,410 | 4,730 | 3,250 | 17,290 |
| 250mm | 400 | - | 4,390 | 5,580 | 2,410 | 12,780 |
| 300mm | 2,280 | 1,190 | 3,870 | 5,690 | 1,510 | 14,540 |
| 350mm | 2,070 | 3,360 | 950 | 3,300 | 1,460 | 11,140 |
| 450mm | 2,050 | 2,240 | 5,590 | 2,250 | 1,900 | 14,030 |
| 500mm | 1,450 | 1,640 | 660 | 2,750 | - | 6,500 |
| 550mm | 1,040 | 1,880 | 1,350 | 770 | - | 5,040 |
| 600mm | - | - | 3,470 | 2,130 | 1,450 | 7,050 |
| 650mm | 1,090 | 130 | 1,090 | 1,030 | 610 | 3,950 |
| 750mm | - | 3,470 | 1,980 | 3,660 | 470 | 9,580 |
| 900mm | 1,700 | 2,440 | 1,590 | 250 | - | 5,980 |
| 1,000mm | 2,020 | 1,360 | - | - | - | 3,380 |
| 1,100mm | 6,320 | - | - | 2,560 | - | 8,880 |
| 1,200mm | 800 | - | - | - | - | 800 |
| 1,300mm | 990 | - | - | 2,460 | - | 3,450 |
| 1,400mm | 1,970 | - | - | - | - | 1,970 |
| 1,500mm | 1,090 | - | 1,330 | - | - | 2,420 |
| 1,600mm | - | - | 1,960 | - | - | 1,960 |
| 1,700mm | - | - | 930 | - | - | 930 |
| 1,900mm | - | 1,160 | 1,720 | - | - | 2,880 |
| 2,100mm | 240 | 2,320 | - | - | - | 2,560 |
| 2,200mm | 3,290 | - | - | - | - | 3,290 |
| 2,300mm | 5,030 | - | - | - | - | 5,030 |
| **Total pipe length (m)** | | | | | | **166,660** |

## *4.3 On Farm Pumping*

### 4.3.1 Pump Capital Cost

The preliminary on-farm pump size and pump capital costs for the piped distribution system and the open channel system are summarised in Table 3.

**Table 3: Preliminary on-farm pump size and pump capital cost**

| Option | Total pump kW | Pump capital Costs |
|---|---|---|
| Pipe | 6,746 | $ 7,623,755 |
| Open race | 14,421 | $ 10,583,810 |

### 4.3.2 Annual Energy Cost

**Table 4: Preliminary on-farm annual operational costs**

| Option | Annual on-farm pumping cost |
|---|---|
| Pipe | $ 2,556,250 |

### 4.3.3 Trade-off Between on Farm Pumping and Pipe Capital Costs

It was found that when sizing the pipe diameters for a lower velocity, pipe capital costs increased due to larger diameters being used. However, the reduction in pump capital cost and annual pumping did not offset the increase in pipe capital. The assumption of supplying minimal pressure to the turnouts under full load is justified.

### 4.3.4 Pressure Delivered Under Different Flow Demands

To demonstrate the pressure variation delivered to the turnouts at different flow demands, eleven representative turnouts were selected located near the top, middle and bottom of the scheme. The pressure delivered to these turnouts (location shown in Figure 4) has been assessed for different flow demand scenarios, ranging from 0 to 100% demand.

Figure 5 shows the pressure delivered to Turnout 387 (located near the top of the scheme), Turnout 602 (located near the middle of the scheme) and Turnout 296 (located near the bottom of the scheme). This shows that for the turnout located near the top of the scheme that under different flow demands the pressure delivered to the turnout varies little. However, for the turnouts located near the middle and bottom of the scheme, some pumping may be required at 100% flow demand (assuming 50 m head is required), but when the flow demand reduces to around 80%, pumping requirements for these turnouts would be minimal.

Figure 6 demonstrates the number of turnouts that would require pumping throughout the season.

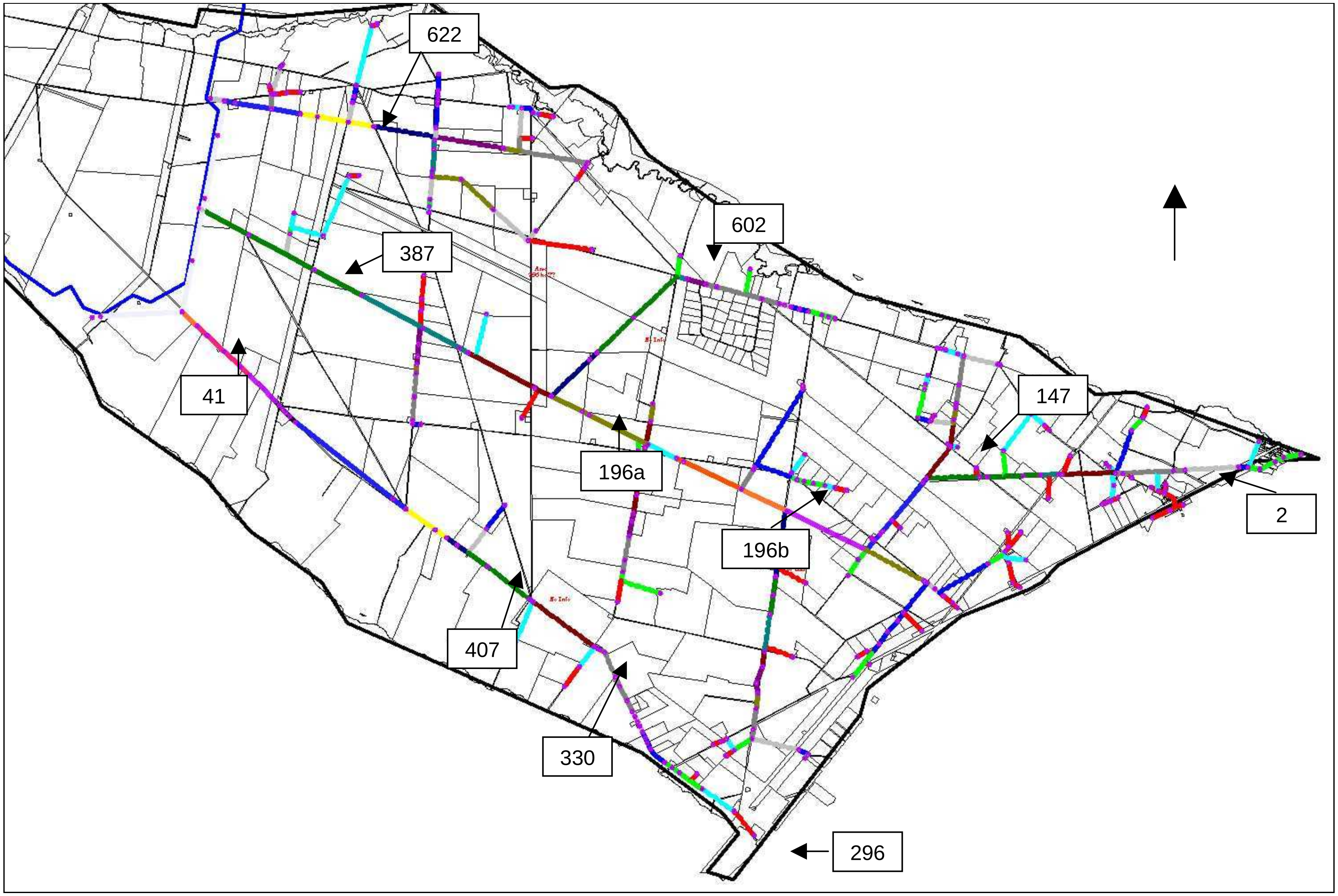



**Figure 4: Option 2 - Pipe Layout and turnout location**

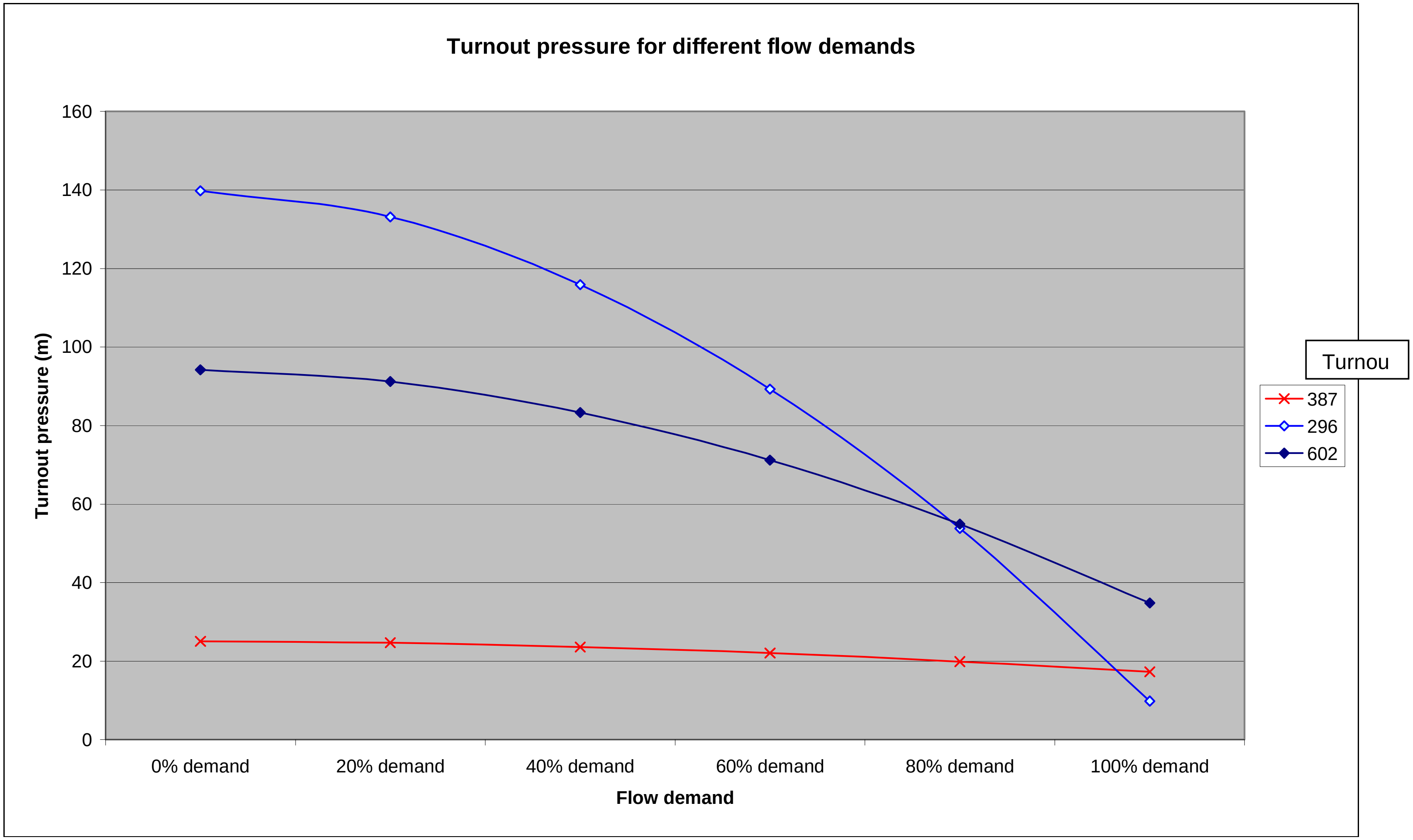



**Figure 5: Turnout pressure for different flow demands, for turnouts located lower within the scheme**

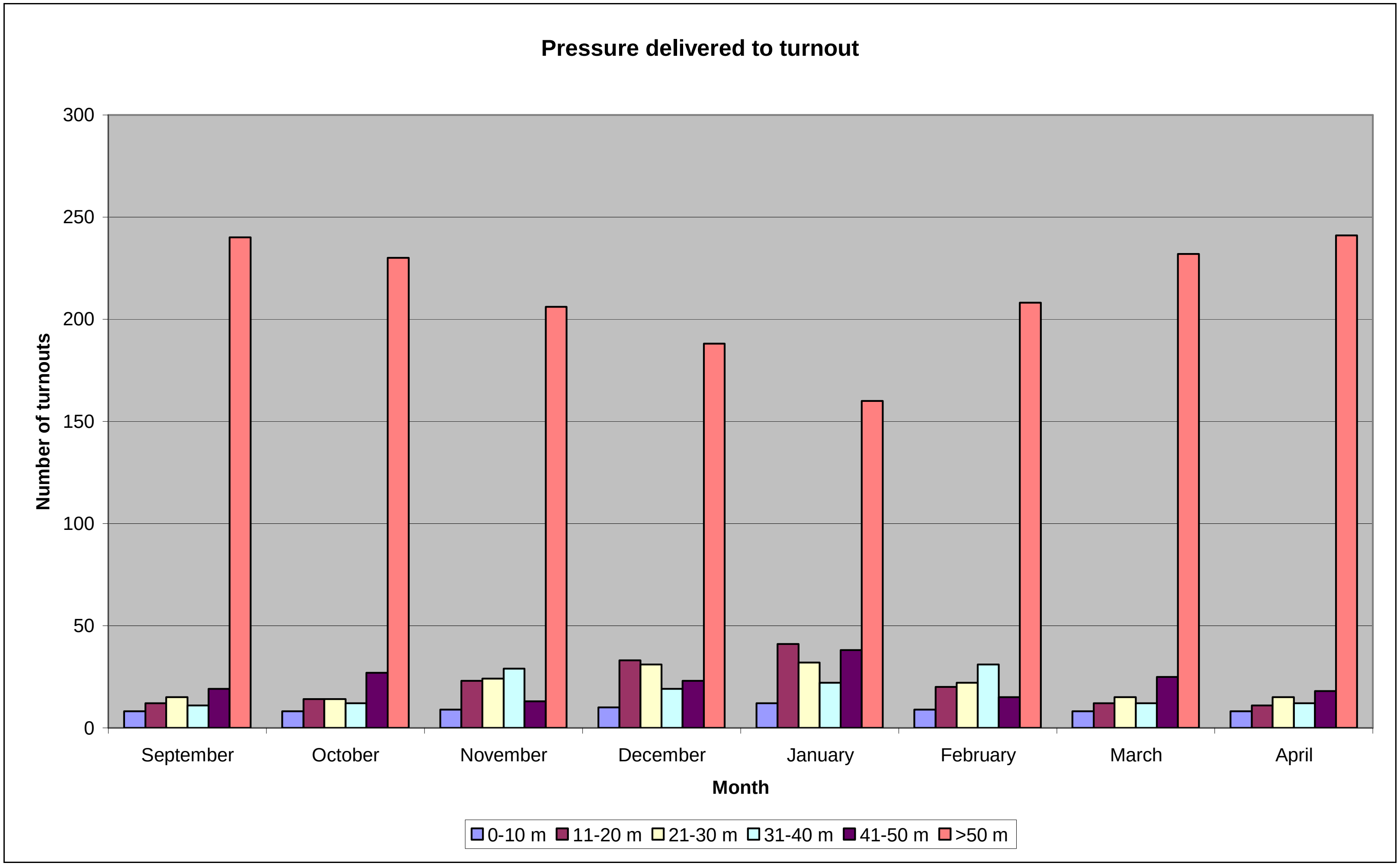



**Figure 6: Turnout pressure for different flow demands, for turnouts located lower within the scheme**

# APPENDIX 3
# CPW CASE STUDY OPEN CHANNEL OPTION

# Contents

# CPW CASE STUDY OPEN CHANNEL OPTION

## 1.0 Introduction

### *1.1 Background*

The piped irrigation distribution network for the case study of the Central Plains Water (CPW) sub-area is described in Appendix 2. Design criteria in terms of peak rate and seasonal volumes at delivery points for the piped and open channel options are the same and are not repeated here. The essential difference from the piped option is that water is delivered at the farm offtake point at ground level. The design issues are therefore related to the layout of the open channel network, the hydraulic capacity of the system along reaches of canal, protection of the canal prism, and structures need for operational control. This appendix describes the basis for the quantification of these issues.

The designs of the CPW canal area were completed on case study sub-area of 36,000 ha located between the Rakaia and Selwyn River below the proposed CPW headrace to the Main South Road.

The open channel network utilised the CPW layout developed by URS, consultants to Central Plains Water Ltd. . The URS network was designed ‘on grade’ and high velocities in the canal occur requiring armouring of the invert. This option was selected by URS to avoid drop structure costs and excessive cuts and fill embankments required on sloping ground to create flat grade canal systems[1].

URS provided a plan showing the basic layout of the scheme which was expanded as shown on Figure 1, to include pipe sub areas to service all farms to the same level of service as a piped scheme. The following details of the CPW canal scheme (refer to Figure 1):

- Location of CPW headrace
- Boundary of the total proposed irrigated area (relevant to this study)
- Property boundaries and property area
- Contour details (10 m contours)
- Proposed open channel layout

[1] The NZ experience of designing a large open channel system on-grade with prism protection is limited, but has been adopted in this study as it is preferred at this stage by CPW consultants. It is likely that costs of the open channel option would be higher if a more conventional cut and fill long section was adopted with drop structures.

- Water at the intake has already been diverted to a primary canal between the Rakaia and Waimakariri Rivers. Significant intake work, fish screens or river training are therefore not accounted for.
- The topography is generally flat with maximum land slopes ranging from 1 in 100 at higher elevations to 0.7 in 100 towards the lower limits. Canal gradients are generally less than maximum land slopes. The open channel layout does not involve complicated plan or elevation changes which can significantly affect costs.
- Groundwater into the canal excavation is not considered significant.
- The land is primarily cleared farmland.
- Not all farms are bounded by the canal network as occur with the pipe network. This is in areas of smaller farm sizes or lifestyle blocks typically on the eastern fringes of the network. To provide the same level of service small pipe networks were utilised to supply these properties in stead of a tertiary canal system.

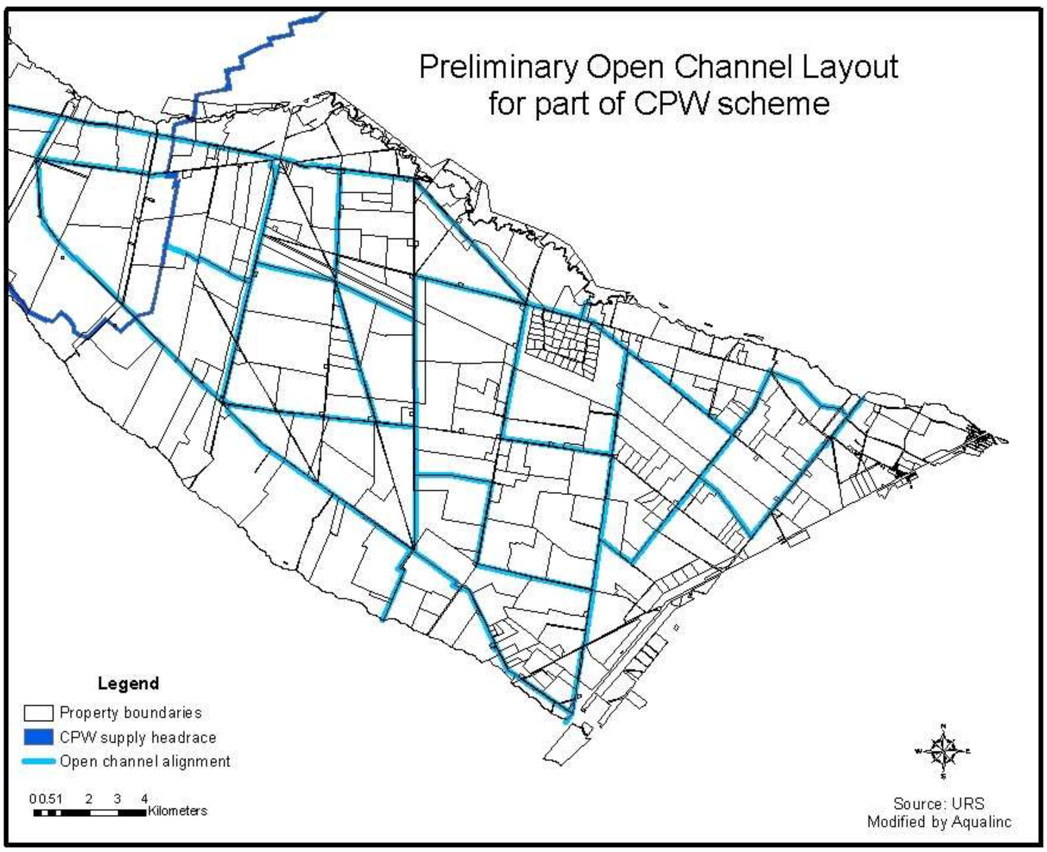



**Figure 1: Preliminary open channel layout for part of CPW scheme**

A summary of the method for designing the piped distribution network for the CPW case study is provided below.

# 2.0 Design Details

Water is to be abstracted from the CPW headrace, and will be delivered to the proposed irrigable area via a primary and secondary open channel developed by URS as a result of landholder and current consent discussions. The water will be delivered to each property using an off-take pond point (turnout) suitable for a pipe pumped offtake. Small areas of the scheme are to be irrigated by a small pipe network to avoid the need for a tertiary canal network.

## *2.1 Irrigated Area*

The total area to be irrigated is approximately 36,000 ha. Within this area, there are 305 properties to deliver water to each property. Some turnouts will deliver water to more than one property. There are 133 properties with turnout flow requirements of less than 1 l/s. These turnouts account for less than 1% of the total flow and are not included within the irrigated area.

## *2.2 System Capacity*

The system capacity has been based on a delivering a flow of 0.6 l/s/ha to each property. The total flow to supply an area of 36,000 ha is approximately 21.6 $m^3$/s.

The design is to be capable of supplying water to each property ‘on demand’ at all times.

## *2.3 Water Source*

The water source is from the CPW headrace and includes three primary offtake points. The intakes considered involve large open ‘U’ shapes structures with gates built into the side of the main canal embankment.

## *2.4 Elevations*

The highest elevation at the CPW headrace is at 240 m amsl and the lowest elevation is at the Main South Road at 63 m amsl.

The contour information as supplied by URS has been used. It is considered appropriate to use 10 m contours as interpolation between these contours gives a reasonable estimation of the lie of the land between the contours.

## *2.5 On Farm Delivery Pressures*

The elevation change over the length of the canal network provides no pressure supply within the main scheme, which means that properties must be fully pumped.

## *2.6 Canal and Pipe Layout and Sizing*

The canal layout was not optimised to minimize capital costs – the information supplied by URS was adopted.

## *2.7 Turnouts*

Turnouts from the scheme distribution system will contain some or all of the following basic components:

- Weir to divert flow from canal
- Culvert
- On farm pond
- Screen
- Pump

One hundred properties comprise small pipe distribution system and will contain some or all of the following basic components:

- Pressure reducing valve and pressure relief valves to control excess pressures
- Flow control
- Flow meter

## *2.8 On Farm Pumping*

Water is to be supplied to each turnout under with no pressure except for the small sub area of pipe scheme.

To aid in the assessment of on-farm pumping requirements, land use projections and monthly and seasonal irrigation demand estimates were scaled from irrigation demand modelling undertaken in the Ashburton region. This was the basis for the criteria used for determining the change in irrigation demand through the irrigation season and the operational costs for on-farm pumping.

Due the variation in pumping pressure and flow required throughout the season, pumps fitted with variable speed drives have been assumed.

### 2.8.1 Irrigation Demand

A water demand scenario for the Ashburton region was modelled in the Canterbury Strategic Water Study (2002), to determine average and peak monthly irrigation demand. A daily time series of potential irrigation demand was calculated in the Ashburton region using daily rainfall and climate data from June 1972 to May 2000 based on the land-use assumptions summarised in Table 1. Both the monthly peak flow demand and average monthly flow demand were calculated.

**Table 1: Assumed land-use for potentially irrigable land**

| Region | Dairying | Intensive Livestock and Dairy Support | Arable |
|---|---|---|---|
| Ashburton | 52 % | 30 % | 18 % |

To estimate the potential irrigation demand for the Rakaia/Selwyn scheme, the data from the Ashburton region has been scaled based on the peak flow difference between the Ashburton and CPW, thus enabling the monthly flow demand to be calculated. The average flow demand as a percentage of the peak flow for each month is shown in Figure 2.

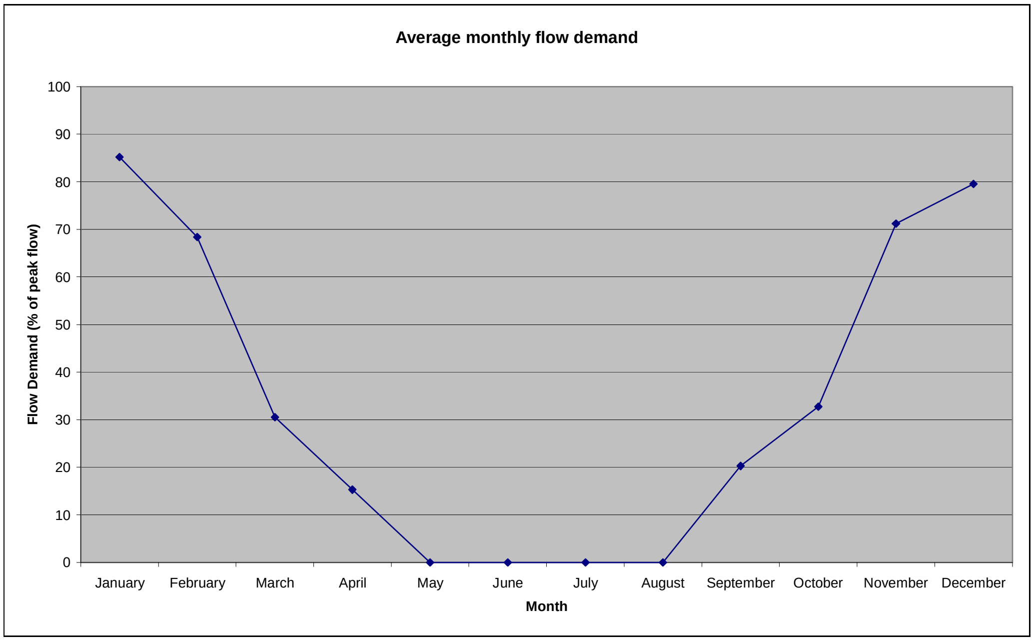



**Figure 2: Average monthly flow demand**

# 3.0 Canal Design

## *3.1 Canal Layout*

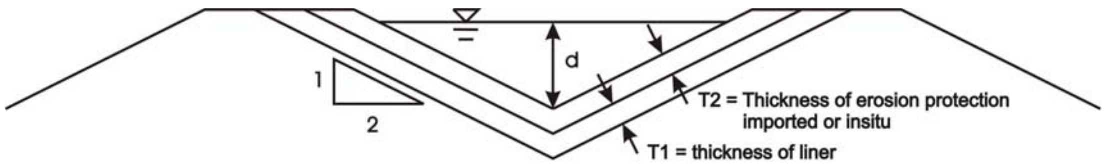
The canal physical layout and flow in each section were developed by URS as shown in Figure 1. This layout does not supply water to all delivery points, so small sections of piped extensions were incorporated to ensure that the delivery ability was similar to the fully piped option. The following steps were then completed to develop the design to price:

- Code each canal section
- Determine canal section sizing based on canal gradients as assessed from 1:50,000 contour plans.
- Calculate erosion liner requirements based on canal velocities
- At each distribution point determine gate requirements
- Determine culverts for road crossings
- Develop a bill of quantities.

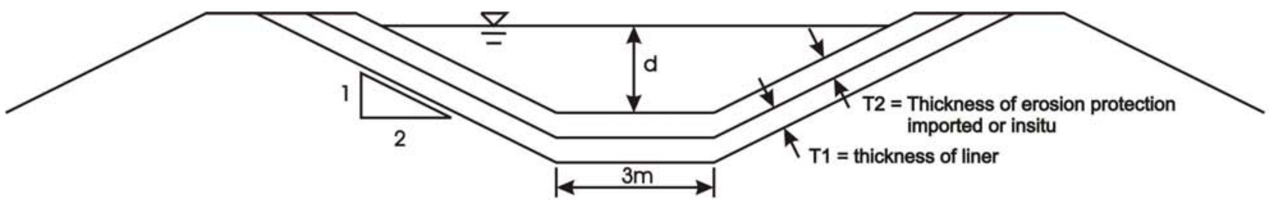
## *3.2 Canal Design Cross Sections*

Two different cross sections were designed to suit the required maximum flow rate of each canal section as shown on Figure 3 below. A triangular cross section was used for lengths of canal with flow rates of less than 2 $m^3$/s. A trapezoidal profile was used for sections with canals with flow rates in excess of 2 $m^3$/s. These two options were chosen from a construction perspective allowing for digger or grader excavation of small canals, and for larger canals flow design sizings to allow economical construction by earth moving equipment commonly used by earthworks contractors.

**Figure 3 – Design canal cross sections utilised**




Triangular cross section for flows less than 2 $m^3/s$




Trapezoidal cross section for flows greater than 2 $m^3/s$

## *3.3 Canal Geology and Design Impacts*

No site-specific testing or investigation of the soil grading curves for design purposes was completed. The erodibility of the canal material was estimated using a typical grading for similar alluvial gravels from the Ashburton area. It was found that the local materials would likely erode at the URS proposed canal gradients and flow rates, and that specific gravel or cobble erosion protection measures would be required for all canal sections.

For low gradients along the canal route (i.e. flatter than 1:400) it was assumed that the lining and armour material could be sourced on site. For steeper gradients the armour material would need to be imported or screened from on-site materials.

Based on the above, a table of estimated per metre costs of earthworks and erosion protection was created for each canal flow and gradient.

## *3.4 Liner Material*

The URS design incorporates no liner material for seepage control. The case study design has assessed that a liner material is required. The thickness of both the liner and erosion protection was assumed to be 0.5 m.

## *3.5 Road Crossing and Culverts*

The number of road crossings was estimated from existing maps and a plan of the proposed scheme extensions. Preliminary culvert diameters were calculated based on the required maximum flow at each road crossing, and are shown on Table 1 below.

### *3.6 Distribution Control Gates*

Control gates are required at nodes where flow goes in more than one direction. The number of nodes was obtained from the proposed scheme extension plan as shown on Figure 1.

### *3.7 Sub Area Pipe Scheme*

As shown in Figure 1 small areas of pipe scheme were included to avoid tertiary canal systems where land or land owner permission for canals was deemed unavailable. The full details of the analysis for the pipe area were the same as for the full pipe scheme option as described in Appendix 2.

Limited design iterations were completed. All 100 properties were deemed to need supply to be provided the same level of service as the piped scheme option. Layout of the pipe was optimised so all properties were connected to the networks.

### *3.8 Quantities and Estimated Costs*

A full description of the general basis for the estimation of unit rates and costs is given in Appendix 5.

# APPENDIX 4
# ALIS CASE STUDY

## Contents

# ALIS CASE STUDY

## 1.0 Introduction

### *1.1 Background*

The Ashburton Lyndhurst Irrigation Scheme (ALIS) currently supplies water from the Rangitata Diversion Race (RDR) to the properties within the scheme via an open channel network.

A case study on the preliminary pipeline layout design and costing of a piped distribution system has been completed for part of the Ashburton Lyndhurst Irrigation Scheme (ALIS) to assess the economics of replacing part of the open channel network with a piped supply. This has been completed to provide the basis for establishing a generic method for comparing the costs of converting an open channel scheme to a piped distribution system. The methodology described hereunder will be a useful guide to similar conversion proposals.

It is proposed that part of the irrigated area currently taking water from Laterals 1, 2 and 3 of the ALIS be supplied water with pipes rather than open races. The main supply will continue to come from the RDR Race.

ALIS provided a plan showing the following details of the ALIS (refer to Figure 1):

- Location of RDR main supply race
- Properties to be irrigated under proposal
- Property boundaries and property area
- Preferred turnout location

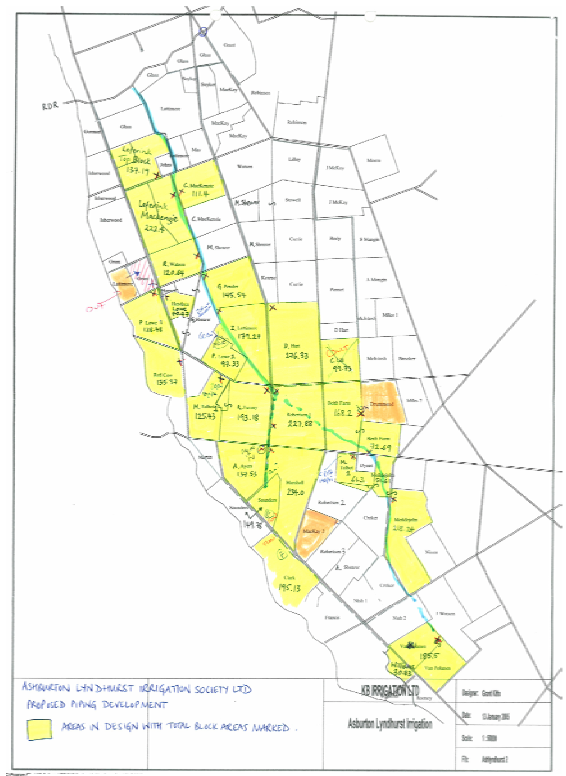



**Figure 1: Part of ALIS Scheme**

A summary of the method for designing the piped distribution network for the ALIS case study is provided below.

## 2.0 Design Details

Water is to be abstracted from the RDR main race, and will be delivered to the proposed irrigable area via a pipe network. The water will be delivered to each property using an off-take point (turnout).

Table 1, supplied by ALIS, summarises the total area, contracted area and the design flow for each property.

**Table 1: Ashburton Lyndhurst Proposed Piping Area – Contracts and Flow rates (updated 18th December 2006).**

| Property Number | Block Area (ha) | Total Contract Area (ha) | Uncontracted Area (ha) | Contract Flow (l/s) | Design Flow (l/s) |
|---|---|---|---|---|---|
| 1 | 137.19 | 137.19 | 0 | 56.3 | 67.6 |
| 2 | 222.4 | 222.4 | 0 | 91.3 | 109.6 |
| 3 | 111.4 | 52.54 | 58.86 | 21.6 | 25.9 |
| 4 | 120.64 | 100 | 20.64 | 41.1 | 49.3 |
| 5 | 47.74 | 16.32 | 31.42 | 6.7 | 8.0 |
| 6 | 145.54 | 145.53 | 0.01 | 59.8 | 71.7 |
| 7 | 128.48 | 55.49 | 72.99 | 22.8 | 27.3 |
| 8 | 97.33 | 97.33 | 0 | 40.0 | 48.0 |
| 9 | 40.47 | 40 | 0.47 | 16.4 | 19.7 |
| 10 | 135.37 | 66.5 | 68.87 | 27.3 | 32.8 |
| 11 | 179.27 | 60 | 119.27 | 24.6 | 29.6 |
| 12 | 276.33 | 225.52 | 50.81 | 92.6 | 111.1 |
| 13 | 144.07 | 144.06 | 0.01 | 59.2 | 71.0 |
| 14 | 125.43 | 125.43 | 0 | 51.5 | 61.8 |
| 15 | 193.18 | 189.82 | 3.36 | 78.0 | 93.6 |
| 16 | 227.88 | 165.1 | 62.78 | 67.8 | 81.4 |
| 17 | 137.53 | 137.52 | 0.01 | 56.5 | 67.8 |
| 18 | 234 | 234 | 0 | 96.1 | 115.3 |
| 19 | 149.78 | 60 | 89.78 | 24.6 | 29.6 |
| 20 | 117.14 | 117.13 | 0.01 | 48.1 | 57.7 |
| 21 | 195.13 | 70.3 | 124.83 | 28.9 | 34.6 |
| 22 | 240.89 | 240.89 | 0 | 98.9 | 118.7 |
| 23 | 61.3 | 35 | 26.3 | 14.4 | 17.2 |
| 24 | 129.17 | 73.05 | 56.12 | 30.0 | 36.0 |
| 25 | 269.85 | 269.85 | 0 | 110.8 | 133.0 |
| 26 | 185.5 | 185.5 | 0 | 76.2 | 91.4 |
| 27 | 30.83 | 30.83 | 0 | 12.7 | 15.2 |
| **Total** | **4083.84** | **3297.3** | **786.54** | **1354.2** | **1625.0** |

The total area of the properties within the area to be irrigated is 4,084 ha, of which only 3,297 ha is contracted for irrigation. The design flow is based on irrigating the contract area using a system capacity of 0.49 l/s/ha (4.25 mm/d). The total flow to supply this area is approximately 1.625 $m^3$/s, assuming no losses. There are a total of 27 turnouts.

The design is to be capable of supplying water to each property 'on demand' at all times.

ALIS has specified a minimum pressure of 60 psi (42 m) to be delivered to the on-farm irrigation system

## *2.1 Elevations*

The highest elevation is at the RDR headrace at 340 m amsl and the lowest elevation is 170 m amsl. The total elevation change over the length of the network is 170 m.

It is considered appropriate to use 10 m contours as interpolation between these contours gives a reasonable estimation of the lie of the land between the contours.

## *2.2 On Farm Delivery Pressures*

The elevation change over the length of the pipe network provides additional pressure within the scheme, which means that properties can be delivered with water under pressure. This additional pressure in the system also enables smaller diameter pipes to be selected, as the elevation gain largely offsets the additional friction losses within the smaller diameter pipes. However, this will increase on farm pumping and a balance between reducing pipe capital costs and on farm pumping costs needs to be reached.

The approach taken was to minimise pipe diameters while maintaining a minimum delivered pressure to the turnout under full demand. In practice, due to the diversity of land use and management practices it is anticipated that the scheme will only operate under full flow demand for short periods of time. For most of the time, particularly at the shoulders of the season, the flow demand will be less than 100% and at these times pressures delivered to the turnout will be higher, thus reducing pumping requirements. Many of the turnouts may not require pumping at all. The trade-off with this approach is that slightly more on-farm pumping is likely to be required than if the pipe diameters were selected based on a lower velocity. Therefore it is important to consider both capital and operational costs when considering the final costs of the scheme[1].

### 2.2.1 Turnout Delivery Pressure

A minimum pressure of 5 m was to be supplied to all turnouts under full flow conditions. This is to minimise issues with pump priming and negative pipeline pressures.

## *2.3 Pressure Control*

Due to the significant elevation change throughout the network, the scheme may be subjected to high static pressures. In the ALIS case, static pressure will be higher than dynamic pressure and was the main focus regarding pressure control.

The scheme distribution pipelines were designed to withstand static pressures. Pressure control on farm as part of the turnout was assumed, which enabled lower pressure class pipe to be used on-farm. Typically lower specification pipes and construction occurs on on-farm irrigation systems, therefore it is important to isolate the risk of high pressure from the network.

Transient pressures should be modelled at the pre-feasibility stage of any design.

## *2.4 Pipe Layout and Sizing*

The pipe layout and pipe sizing was optimised to minimise the capital cost of the distribution pipeline to deliver a minimum of 5 m pressure to the turnouts.

It was assumed that there were no pipe layout constraints, that the pipeline was not restricted to roads and property boundaries, and that disruption to existing services would not be an issue.

## *2.5 Turnouts*

Turnouts from the scheme distribution system will contain some or all of the following basic components:

- Pressure reducing valve and pressure relief valves to control excess pressures

[1] In the ALIS situation, it is possible – because of topography -- to obviate the need for any on-farm pumping with increases in some pipe sizes with capital cost increase.

- Flow control
- Flow meter

### 2.5.1 Turnout Location

The preferred turnout location has been shown on the plan provided by ALIS (Figure 1).

For the purposes of cost comparison, two options are to be considered; one comparing the pipe layout costs for a scheme designed to deliver water to the turnouts at the specified location and the other option based on a pipe layout whereby the turnout location is flexible.

## *2.6 Pipe Materials*

Although any pipe type could be considered, fibre reinforced pipe (FRP) has been used for the design, one of the reasons being it has the ability to withstand high pressures. Also, the risk of the pipe deteriorating with age is low, so that the pipe roughness is unlikely to increase, thus scheme performance should be maintained throughout the pipes life. Nominal diameters have been used within the design.

## *2.7 On Farm Pumping*

Water is to be supplied to each turnout under pressure. However, due to friction losses or changes in elevation along the pipe network, a reduced amount of on-farm pumping may be required. To operate the on-farm irrigation system effectively, a minimum pressure of 42 m (60 psi) has been specified by ALIS. Where less than 42 m pressure is delivered under gravity, small on farm booster pumps will be required.

To aid in the assessment of on-farm pumping requirements, land use projections and monthly and seasonal irrigation demand estimates were scaled from irrigation demand modelling undertaken in the Ashburton region. This was the basis for the criteria used for determining the change in irrigation demand through the irrigation season and the operational costs for on-farm pumping.

Due the variation in pumping pressure and flow required throughout the season, pumps fitted with variable speed drives have been assumed.

### 2.7.1 Irrigation Demand

A water demand scenario for the Ashburton region was modelled in the Canterbury Strategic Water Study (2002), to determine the average and peak monthly irrigation demand. A daily time series of potential irrigation demand was calculated in the Ashburton region using daily rainfall and climate data from June 1972 to May 2000 based on the land-use assumptions summarised in Table 2. Both the monthly peak flow demand and average monthly flow demand were calculated.

**Table 2: Assumed land-use for potentially irrigable land**

| Region | Dairying | Intensive Livestock and Dairy Support | Arable |
|---|---|---|---|
| Ashburton | 52 % | 30 % | 18 % |

To estimate the potential irrigation demand for the Rakaia/Selwyn scheme, the data from the Ashburton region has been scaled based on the peak flow difference between the Ashburton data and ALIS, thus enabling the monthly flow demand to be calculated. The average flow demand as a percentage of the peak flow for each month is shown in Figure 2.

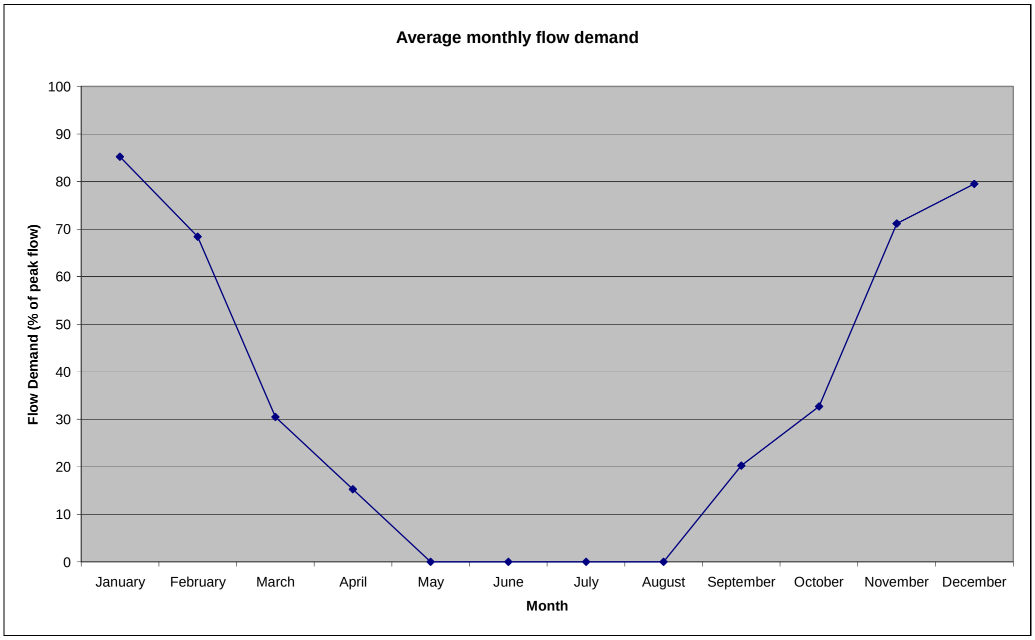



**Figure 2: Average monthly flow demand**

# 3.0 Hydraulic Design

The plans showing the property boundaries and scheme layout, supplied by ALIS, was imported into Irricad™ irrigation design software.

Firstly, the pipe layout was optimised based on reducing pipe capital cost.

Secondly, a detailed hydraulic analysis was completed, to finalise the pipe diameters of the network to ensure all design requirements and appropriate design limits were met.

Thirdly, based on the finalised pipe layout and pipe diameters, on-farm pumping costs were estimated.

Finally, an assessment on the trade-off between pipe capital cost and on-farm pumping was completed based on considering the NPV for the network.

## *3.1 Pipe Layout*

### 3.1.1 Design Options

During the pipe layout optimisation process, two design options for designing the pipe layout to deliver water to the turnouts were considered:

1. Pipeline based on supplying water to the turnout location as specified by ALIS (Figure 1)
2. Pipeline based on supplying water to a turnout location that is flexible within the property (Figure 2).

For each pipe layout options, the following method was followed.

### 3.1.2 Method

**Entering data into Irricad**
Based on the plans supplied by ALIS, the following information was entered into Irricad$^{TM}$ irrigation design software

- Scheme boundary
- RDR head race
- Property boundaries
- Contour information

All turnouts were entered into the modelling software based on supplying each property at the required flow rate determined from the scheme system capacity (0.49 l/s/ha) multiplied by area of the property. Then the main distribution pipeline for Options 1 and 2 were entered taking the most direct route possible to minimise the length of larger diameter pipe. Lateral pipelines branching off from the main distribution pipe were used to supply the turnouts.

**Pipe layout optimisation**
To optimise the pipe layout, changes were made to the layout while comparing pipe capital costs to assess whether the revised layout was more cost effective.

To effectively compare capital costs between each scenario, a quick assessment of the pipe diameters required throughout the network for different layouts is required. The method needs to be repeatable and provide for a consistent and comparative approach for assessing the different layouts

To quickly assess the pipe sizes for each pipe layout iteration, the pipe diameters throughout the entire network were sized based on a maximum velocity. The maximum velocity was selected so that a positive (essentially greater than 1 m) pressure was delivered to the majority of turnouts and to ensure that the pressure within the main distribution pipe was gaining down the network. This approach meant that typically only pipe diameters on the laterals needed to be adjusted to ensure all turnouts received positive pressure when finalising pipe diameters (see below). The maximum velocity was set to 3 m/s.

Cost savings were made by directing the flow from the main pipeline into smaller branch mains as high as possible in the system, thus allowing a smaller diameter main pipe to be selected. Generally, the cost saving gained by reducing the larger diameter pipe was more than offset by the cost in the increased length of smaller pipe.

Also, for Option 2, the length of laterals was reduced by relocating the turnouts. Turnouts were positioned as close as possible to the main delivery pipe to reduce the incidence of two pipes bordering one property. In some cases, this resulted in some turnouts being positioned near the bottom, rather than the top of the property.

## *3.2 Pipe Diameter*

Once the pipe layout was optimised, the pipe diameters were finalised.

Firstly, the turnouts were identified where the delivered pressure was less than the minimum pressure of 5 m. Then pressure loss was checked along the lateral pipes. Where small diameter pipes had high friction losses over a short distance (particularly at the ends of the lateral), these pipes were upsized. Following that, pipes along the lateral which had the highest velocity were upsized until the minimum of 5 m pressure was delivered to all turnouts on that lateral.

The velocity in all pipes was checked to ensure that they were within acceptable velocity limits to reduce the risk of water hammer. Also, static and dynamic pressures were assessed throughout the scheme and selected pipe classes checked to ensure that the pipe pressure limits were not exceeded.

## *3.3 On Farm Pumping*

### 3.3.1 Pump Size

Using the final pipe layout and pipe diameter, the pressure delivered to each turnout at 100% flow demand, i.e. when all turnouts were operating, was determined. Based on a minimum pressure of 42 m to operate the on farm irrigation system, the turnouts that required on-farm pumping and the pump head required was identified.

Assuming a pump efficiency of 75% and a motor efficiency of 90%, the pump size required at each turnout was calculated.

Using pump capital costs (supplied by Flowserve) and electrics cost data (supplied by Nairn Electrical) a relationship between capital cost and pump size was derived for a variable speed drive pump, as follows.

Pump capital cost ($) = 571.5 x Pump size (kW) + 15,196

Based on this data total pump costs were calculated.

### 3.3.2 Pump Energy Cost

To enable calculation of the seasonal pump energy cost the pressure delivered to each turnout for the average monthly flow demand was modelled (described above). This allowed average monthly pumping requirements to be calculated.

The number of hours that the turnout would have been operating at maximum flow within that month has been calculated based on the flow demand. For each month within the irrigation season, the on-farm pumping requirement has been calculated and then combined to give total season pumping requirements.

Based on the following energy charges within the region (supplied by Meridian), the annual energy costs were calculated:

- Daily charge $2.82/day = $1029/yr
- Energy charge 0.13c/kWh
- Capacity charge 0.32c/kVA/day = $123/kW/year (assuming a power factor correction of 0.95)

# 4.0 Results

## *4.1 Pipe Layout and Sizing*

The greatest cost savings could be made when the route was not constrained to property boundaries and road corridors, which allowed the most direct pipeline route to be chosen. This reduced the length of larger diameter pipe, which is where the majority of the cost savings could be made.

The pipe diameter and pipe class was selected to meet velocity and pressure requirements. The pipeline bill of materials for Options 1 and 2 are summarised in Table 3 and Table 4.

**Table 3: Option 1 - bill of materials - pipe length**

| | **Pipe Class** | | | | | | **Total pipe length (m)** |
|---|---|---|---|---|---|---|---|
| **FRP** | **PN3** | **PN6** | **PN9** | **PN12** | **PN15** | **PN18** | |
| 100mm | 0 | 0 | 130 | 0 | 330 | 0 | 460 |
| 150mm | 0 | 0 | 780 | 0 | 2,220 | 1,170 | 4,170 |
| 200mm | 330 | 0 | 1,900 | 0 | 320 | 0 | 2,550 |
| 250mm | 0 | 0 | 2,170 | 2,520 | 2,400 | 1,400 | 8,490 |
| 300mm | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 350mm | 0 | 0 | 0 | 1,210 | 1,340 | 0 | 2,550 |
| 450mm | 0 | 0 | 0 | 400 | 400 | 0 | 800 |
| 500mm | 0 | 0 | 0 | 1,770 | 0 | 0 | 1,770 |
| 600mm | 0 | 0 | 0 | 490 | 0 | 0 | 490 |
| 650mm | 0 | 0 | 1,040 | 890 | 0 | 0 | 1,930 |
| 750mm | 0 | 0 | 1,680 | 0 | 0 | 0 | 1,680 |
| 900 mm | 2,400 | 2,540 | 190 | 0 | 0 | 0 | 5,130 |
| **Total pipe length (m)** | | | | | | | **30,020** |

**Table 4: Option 2 - bill of materials - pipe length**

| | **Pipe Class** | | | | | | **Total pipe length (m)** |
|---|---|---|---|---|---|---|---|
| **FRP** | **PN3** | **PN6** | **PN9** | **PN12** | **PN15** | **PN18** | |
| 100mm | 0 | 0 | 350 | 0 | 0 | 0 | 350 |
| 150mm | 0 | 0 | 1,270 | 0 | 1,060 | 310 | 2,640 |
| 200mm | 0 | 0 | 1,160 | 940 | 120 | 0 | 2,220 |
| 250mm | 0 | 0 | 870 | 1,110 | 4,700 | 1,040 | 7,720 |
| 300mm | 0 | 0 | 0 | 0 | 460 | 0 | 460 |
| 350mm | 0 | 0 | 0 | 1,990 | 0 | 0 | 1,990 |
| 450mm | 0 | 0 | 0 | 1,190 | 350 | 0 | 1,540 |
| 500mm | 0 | 0 | 0 | 330 | 0 | 0 | 330 |
| 600mm | 0 | 0 | 0 | 640 | 0 | 0 | 640 |
| 650mm | 0 | 0 | 0 | 250 | 0 | 0 | 250 |
| 750mm | 0 | 0 | 2,660 | 700 | 0 | 0 | 3,360 |
| 900 mm | 2,400 | 2,540 | 200 | 0 | 0 | 0 | 51,40 |
| **Total pipe length (m)** | | | | | | | **26,640** |

Table 3 and Table 4 shows that the total pipe length required for Option 1 is approximately 13% more than for Option 2 and consequently the pipe capital cost for Option 1, was approximately 4% more expensive that the Option 2, thus showing the savings made by having a flexible water supply location.

Once a main layout had been chosen, it was found that minor changes in the layout actually resulted in only small percentage changes the overall pipe capital cost. It was not considered necessary to perform numerous iterations for the purpose of the study.

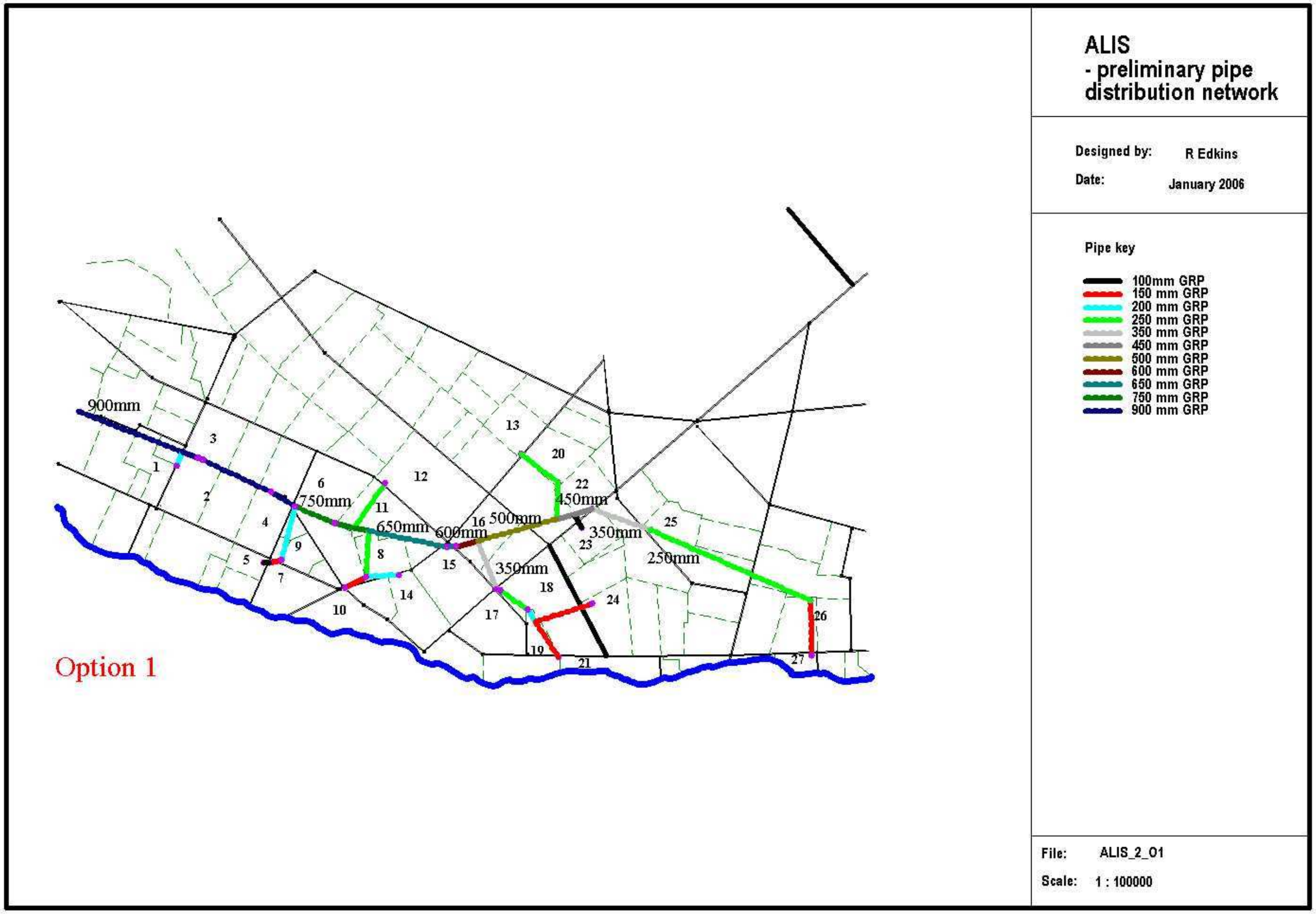



**Figure 3: Option 1 proposed pipe layout**

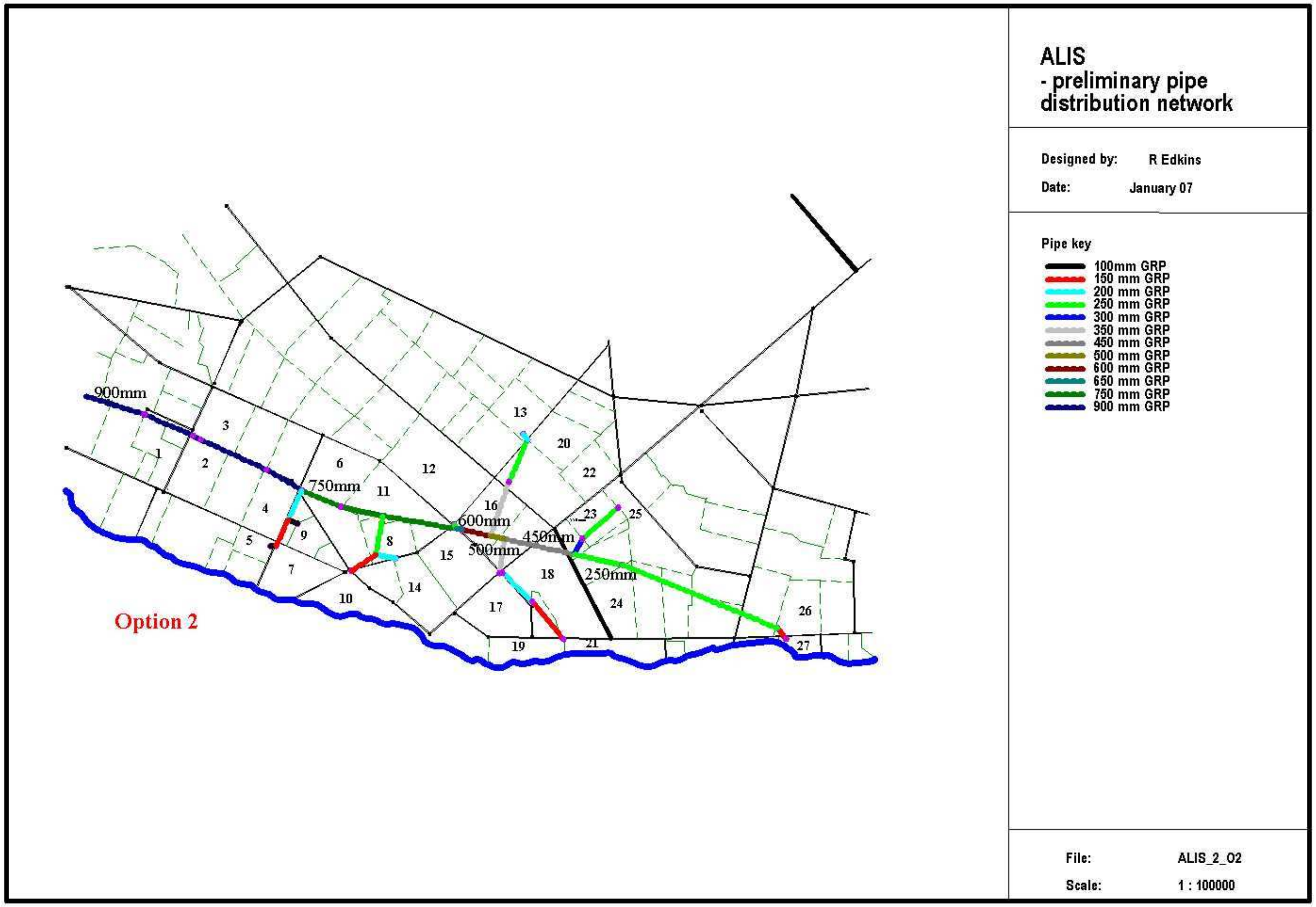



**Figure 4: Option 2 - proposed pipe layout**

## *4.2 On Farm Pumping*

### 4.2.1 Pump Capital Cost

The preliminary on-farm pump size and pump capital costs for the two piped distribution system options are summarised in Table 5.

**Table 5: Preliminary on-farm pump size and pump capital cost**

| Option | Total pump kW | Pump capital Costs |
|---|---|---|
| Option 1 | 285 | $ 512,244 |
| Option 2 | 214 | $ 410,880 |
| Open channel | 893 | $ 760,571 |

### 4.2.2 Annual Energy Cost

**Table 6: Preliminary on-farm annual operational costs**

| Option | Annual on-farm pumping cost |
|---|---|
| Option 1 | $ 57,013 |
| Option 2 | $ 48,350 |
| Open channel | $ 359,311 |

Table 5 and Table 6 show that the Option 1 requires more pumping than for Option 2. This is likely to be related to the additional pipe length required to supply the turnouts at the specified locations which would be increasing friction losses within the scheme.

### 4.2.3 Trade-Off Between on Farm Pumping and Pipe Capital Costs

It was found that when sizing the pipe diameters for a lower velocity, pipe capital costs increased due to larger diameters being used. However, the reduction in pump capital cost and annual pumping did not offset the increase in pipe capital. The assumption of supplying minimal pressure to the turnouts under full load is justified.

### 4.2.4 Pressure Delivered Under Different Flow Demands

The delivery pressure to each turnout changes under different flow demands. To demonstrate this, the pressure delivered to four turnouts (one located near the top, two near the middle and one near the bottom of the scheme) under different flow demands for Option 2 are shown in Figure 4. The location of these turnouts is shown in Figure 3.

The turnout located near the top of the scheme only has a minor variation in pressure under different flow demands. The turnouts located near the middle and bottom of the scheme, some pumping may be required at 100% flow demand (assuming 50 m head is required), but when the flow demand reduces to around 80%, pumping requirements for these turnouts would be minimal.

Figure 5 demonstrates the number of turnouts that would require pumping throughout the season.

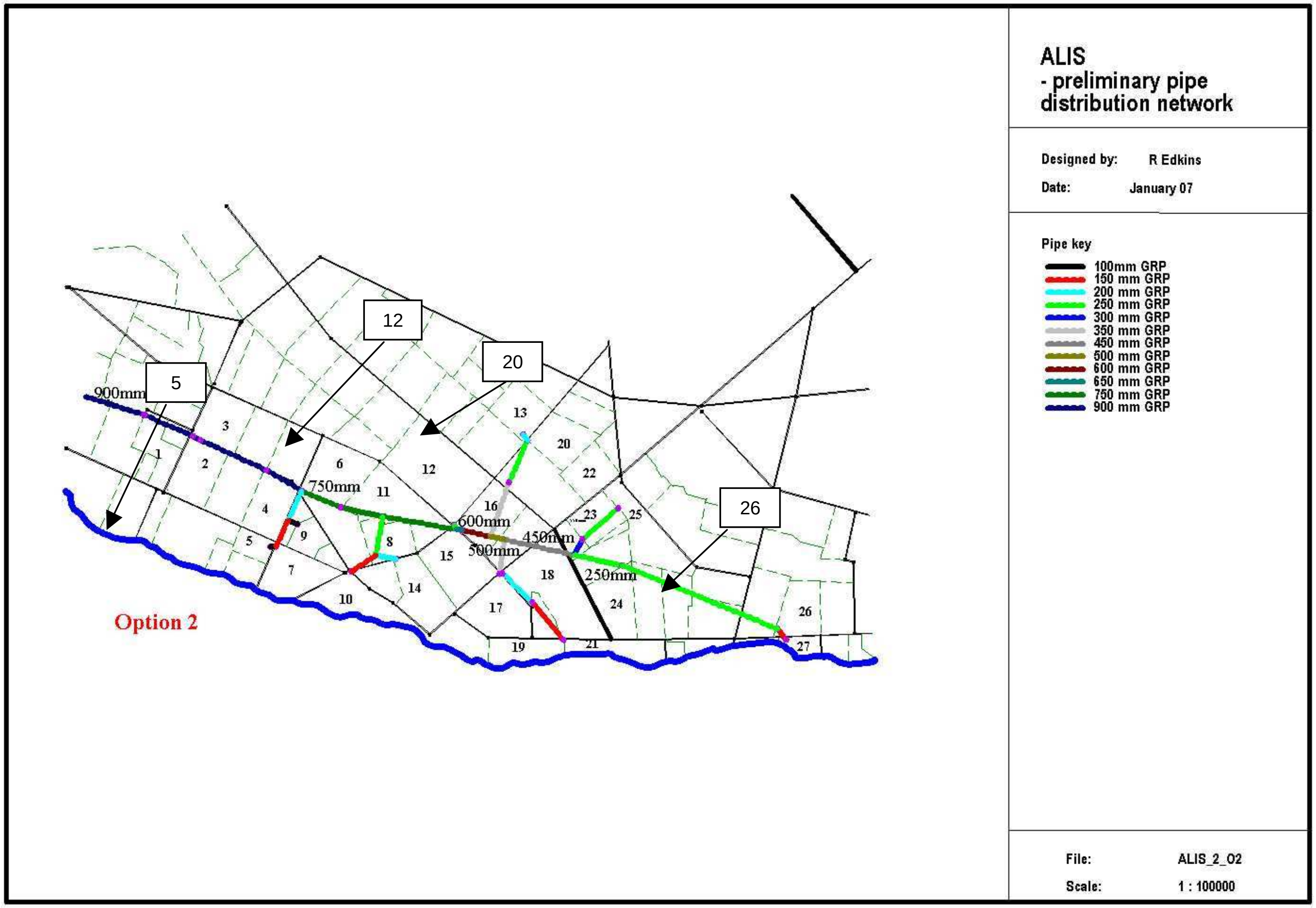



**Figure 5: Location of turnouts to show pressure change dependent on load**

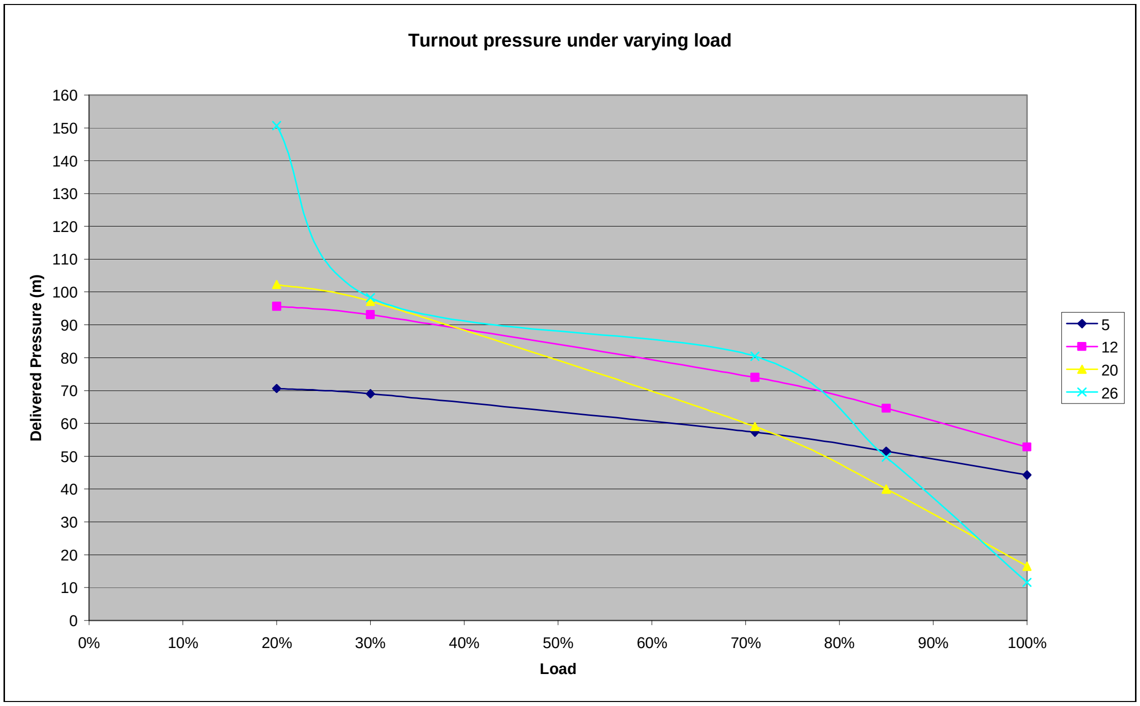



**Figure 6: Turnout pressure for different flow demands, for turnouts located lower within the scheme.**

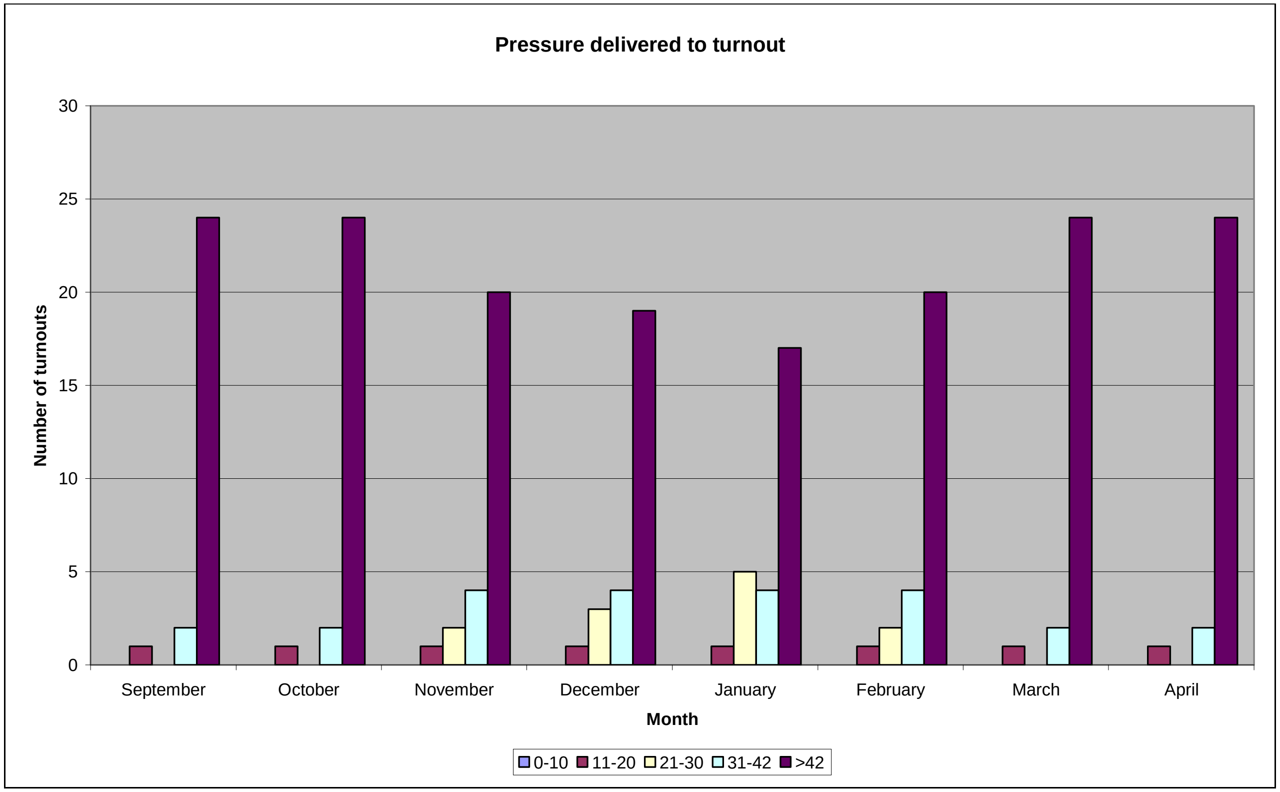



**Figure 7: Turnout pressure for different flow demands, for turnouts located lower within the scheme**

# APPENDIX 5
# BASIS FOR ESTIMATION OF COSTS

## Contents

# BASIS FOR ESTIMATION OF COSTS

## 1.0 Purpose of Cost Estimate

A cost estimate is an integral component of assessing an irrigation scheme's viability. At each stage of a scheme's consideration the level of understanding, detail and design are improved upon, and the accuracy of the cost estimate increases. Generally, a cost estimate would be completed at each of the following stages:

- Preliminary scheme assessment, accuracy within 50%
- Pre feasibility design, accuracy within 30%
- Feasibility design, accuracy within 20%
- Final design, accuracy within 10 %
- Tendered prices from contractors, accuracy within 5 to 10%

The accuracy of the estimate will often vary significantly from the original preliminary scheme concept stage to receiving a final constructed price. Preliminary scheme assessments of cost often underestimate full scheme costs, and a true estimate of cost is often not obtained until a feasibility design stage is complete. Experience indicates that even when fixed prices from contractors are received, the final scheme cost including commissioning modifications during construction and variations will be above the agreed price.

When assessing an irrigation scheme and undertaking financial viability analysis, consideration of what level of accuracy the price estimate used is, should always be factored into the assessment. This appendix is designed to give guidance to the preparation of cost estimates for developments of the scale involved in open channel and piped distribution systems.

## 2.0 Sources of Cost Estimates

Construction cost estimates can be prepared by a number of different people or organisations and the basis of the costs estimate derived in a number of ways.

Primary sources of costs estimate often include:

- Scheme engineering designers
- Contractors
- Material Suppliers
- Correlation from schemes already constructed

Scheme organisers should recognise that no one person or organisation is likely to have all prerequisite skills to advise owners in all aspects of large scheme development. It is advisable that input from several people with various skill sets should be obtained throughout the design and costing stage.

# 3.0 Cost Estimates Integrated with Design

In the initial stages of investigation, the basic layout of a scheme is derived via consideration of factors such as land ownership, availability of easements and topographic constraints etc. Up to and including prefeasibilty level investigation, design iterations to optimise a scheme and or reduce costs are often not completed in detail. At the feasibility stage, however, it is important that consideration of a range of layout options, construction methods and materials is undertaken, as both canal and pipe scheme costs can vary significantly based on what can seem minor assumptions.

Examples of design and construction considerations that could influence scheme costs include:

## *3.1 Pipe Schemes*

- Twin lining pipes in trenches to reduce the need for single large diameter pipes.
- Utilising several pipe material types for different parts of the scheme based on pressure rating, diameter, depth of embedment, surcharging etc.
- Avoiding complicated layouts as the costs of bends and anchor blocks can be a significant portion of the overall scheme cost.
- Pipe layouts can run through productive farm land provided enough ground cover is in place above the crown of the pipe. The layout should not necessarily avoid productive land.
- Vary pipe diameters where only a single pipe diameter is required by design. This allows the ability to 'nest' pipes within each other for transport purposes. For example only four 1.2.m diameter pipes can be carried in a shipping container. Sixteen pipes can be carried in one container (weight permitting) if a 1.2 m, 1.0 m, 0.8 m, 0.6 m and 0.4 m pipe are nestled within each other,'
- Varying designs for velocity and friction losses to control excess pressure and avoid expensive pressure control devices.
- Accepting all properties will not receive maximum irrigation equipment operation pressures. Set a minimum supply pressure of 5 m for example to avoid negative pressures issues.
- Scheme layout affects costs. The ALIS case study shows that a 'long and narrow' layout can cost more per hectare than a scheme such as the CPW case study which has a more 'square' layout overall. These two case studies highlight the effect of the high cost of the large principal pipe line delivery systems.

## *3.2 Canal Schemes*

- Assessing canal seepage losses and the need for earth or artificial linings to reduce it.

- Canal gradients significantly affect the layout and excavation costs of canals based on the site topography. Steepening canals and accepting higher water velocities can often be cheaper than constructing concrete drop structures to control canal velocities but has corresponding high scour protection requirements of the canal invert.
- Designing appropriate canal sections given the local geological conditions and construction equipment to be utilised.
- Culverts, drop structures, gate structures, offtake structures, preliminary and general costs add significantly to scheme costs. In early stages of investigation some of these factors are overlooked.
- Removal of unsuitable materials during construction can be a significant hidden cost.

### *3.3 Other Variables Potentially Affecting Scheme Costs*

Irrigation schemes involving multiple properties typically take several years to implement from first conception through to construction and operation. It is common to see price estimates carried forward without revision for some time and when reassessed the viability of a scheme has changed for a number of factors.

Several commonly occurring changes that may affect price estimates include:

- Changing Resource consent requirements.
- Changing land use and owners may alter scheme design constraints.
- Inflation.
- State of the economy. A busy economy generally means higher contract prices as competition is reduced.
- Scale effects. Typically the larger the project the less the unit costs for scheme construction.

Selection of designers and contractors for the project may affect the cost for a scheme, relevant considerations include:

- Contractor size. Larger firms often have higher fixed overheads and invest in more aspects such as quality assurance documentation, etc. and at times may not be competitive against small firms. Smaller firms can often be more costs competitive but are limited in the size of the projects they could construct. Therefore balancing the size of the project against contractor resources should be considered.
- The method of contract between the owners and the contractor. Contracts are used to define roles, set standards and manage or define risk sharing. The more risk the contractor takes the more expensive the project.
- The design risk scheme. Owners are willing to take based on variations in material suitable for a single purpose, techniques or design.
- Schemes ‘over or under engineered’ can have significant hidden costs. ‘Over’ engineered schemes will typically have up front higher costs, but lower ongoing operation and maintenance costs. ‘Under’ engineered schemes will have hidden and ongoing operational and maintenance costs.

- The experience of pipe installation and earthworks contractors plays a significant role in the scheme overall cost and effective completion of a successful scheme. The value of experienced contractors (and designers) can not be overstated but is difficult to put a price on. Checks on references in tenders should be undertaken to support contractors and marketing claims of suppliers.

There are numerous methods of contract between owners and contractors. In order of decreasing costs the common contract methods are:

- Lump sum price for the completed project. Payment made monthly based on percentage complete.
- Measure and value what is constructed based on designs. Requires a robust design and schedule of rates and quantities.
- Day rates for hire of contractor's personnel and equipment. Requires a robust design but also appropriate supervision. Reduced construction costs are partially offset by increased supervision costs.

Consideration to at least the above issues should be incorporated into cost assessment, design, contract preparation and the contractor selection process.

# 4.0 Additional Costs Required for Full Budget Estimation

The following lists costs apart from construction that require inclusion in estimates and can contribute a significant portion of the completed costs. Some of these costs are likely to be overlooked in the early stages of investigation.

- Design fees - allow a range of 2% to 8%.
- Surveying - allow a range of 0% to 2%.
- Legal fees including easements - allow a range of 1% to 4%.
- Resource consent fees - allow a range of 1% to 10%.
- Associated studies often for Resource consents - allow a range of 1% to 5%.
- Building consent fees and government levies. Sometimes these can be negotiated down with council under special clauses of the building act. Allow a range of 0% to 1%.
- Contract document preparation - allow a range of 1% to 3%.
- Contract management and supervision - allow a range of 1% to 5%.
- Peer reviews of design - allow a range of 1% to 2%.
- Import duties - allow a range of 0% to 2%.
- Freight of goods - allow a range of 0% to 1%.
- Contingency - allow a range of 0% to 15%.

# 5.0 Construction Cost Estimation

## *5.1 Establishing Unit Costs*

Establishing quantities and unit costs for construction is the preferred method for estimating the cost of a scheme.

Unit costs are commonly derived from

- Material suppliers
- Designers
- Contractors
- Published data such as the quantity surveyor construction costs handbook, 'Rawlinsons New Zealand Construction Handbook' (published yearly).
- Transposing until costs from previous schemes or rules of thumb. This method is generally only acceptable for preliminary and pre-feasibility level cost estimates.

Depending on the stage of the study, estimating unit costs requires a focus on the critical cost items and those that may vary significantly, for example a canal clay liner that due to local condition is wet of optimum moisture content can lead to significant construction difficulties. The same clay in another region may be dry of optimum and ideal for placement following moisture conditioning.

Line items particularly sensitive to changes in quantity or unit rate should be subject to the closest consideration. Such items generally include:

## *5.2 Pipe Schemes*

- Pipe raw cost
- Pipe bends
- Pipe transport cost
- Pipe trench excavation
- Pipe bedding material
- Pipe haunch material
- Back fill material
- Anchor blocks
- Above ground pipe and supports
- Farm offtakes

## *5.3 Canal Schemes*

- Cut to fill
- Cut to waste of unsuitable materials
- Canal lining costs
- Rock armouring of canal
- Gully crossing including culverts
- Culverts and spillways
- Reinstatement topsoil, fencing etc
- Drop structures

Intake design for both types of schemes is unique to each site. Challenges for design of new river intakes include provision for durability, reliability, sediment control, potential effects on river scour, maintenance, and fish screening.

# 6.0 Operational Costs

In assessing operational costs the following at a minimum should be considered for new schemes.

## *6.1 Pipe and Canal schemes*

- Director fees
- Insurances
- Rates
- Power, telephones, office administration.
- Rents
- Easement fees ongoing
- Equipment and sundries
- Transport
- Wages
- ACC and other wage associated costs
- Training costs
- Water supply fees

## *6.2 Pipe Schemes*

- Routine valve and farm offtake replacements
- Pump maintenance costs
- Cathodic protection if required
- Pipe lining minor repairs
- Valve blockage

## *6.3 Canal Schemes*

- Rock lining repairs
- Canal lining repairs
- Gate or screen maintenance
- Weed spraying
- Vandal damage

# 7.0 Maintenance Costs

Maintenance costs are considered non recurring costs that are required to maintain the long term viabilities of infrastructure. Assessing maintenance costs needs to be a through exercise if undertaken at early stages of a project and utilisation of existing scheme unit rates often can provide a reasonable estimate of potential costs. Typical costs may include:

**Table 1: Pipe Schemes**

| Item | Interval |
|---|---|
| Pipe lining repairs | Infrequent |
| Jointed pipes seal degradation | Unlikely |
| Pipe burst requiring replacement | Infrequent |
| Council or Transit road realignments requiring pipe realignment | Infrequent |
| Valves, etc | Infrequent |
| Inspection and material testing | Infrequent |
| Intake including fish screen repairs | Common |

**Table 2: Canal Schemes**

| Item | Interval |
|---|---|
| Canal rock and lining repairs | Infrequent |
| Gates and screen damage or replacement | Infrequent |
| Culvert, drop structures, distribution structure repairs | Infrequent |
| Intake or fish screen repairs | Common |
| Canal or head pond sediment removal | Common |
| Storm damage from excessive inflows | Infrequent |
| Spillway repairs | infrequent |

# 8.0 Case Study – CPW Piped Scheme

The following sections document assumptions and methods used for a preliminary cost estimate for part of the Central Plains Irrigation Scheme. The area under consideration contains 36,000 Ha of irrigable land. The ground surface is regular, comprising an alluvial terrace gently sloping to the southeast. Subsurface conditions are expected to comprise free-draining gravels overlain by a variable thickness of silty gravel and topsoil. The distance between the offtake at the main distribution canal and the farthest extent of the area considered is approximately 150m vertical height and 28km horizontal distance.

No site visits, survey, ground investigations, or detailed design checks have been undertaken to produce this cost estimate. Published maps, property boundaries and regional geological plans for the area have been reviewed and applicable information incorporated where appropriate.

The preliminary layout of the piped distribution scheme has been developed by Aqualinc Research Ltd utilising “Irricad” pipe network design software.

## *8.1 General Background*

The following notes describe features of the Central Plains Water (CPW) sub area that affected how the price estimate for the scheme was developed.

- Water at the intake has already been diverted to a primary canal between the Rakaia and Waimakariri Rivers. Significant intake work, fish screens or river training are not accounted for.
- The topography is generally flat when compared to other parts of New Zealand. The pipe layout does not involve complicated plan or elevation changes which can significantly affect costs of trenching, bend manufacture and thrust blocks.
- Groundwater into the trench excavation is not considered significant.
- The land is primarily cleared farmland.
- The price estimate is considered a preliminary cost estimate. Scheme layout was developed by Aqualinc Research Ltd utilising “Irricad” pipe software.
- The majority of item estimates are based on a combination of “first principle” unit rates and comparison with other recently constructed schemes. Pipe installed unit costs (the largest component) were developed from first principals.

The scheme layout is shown in Figure 1.

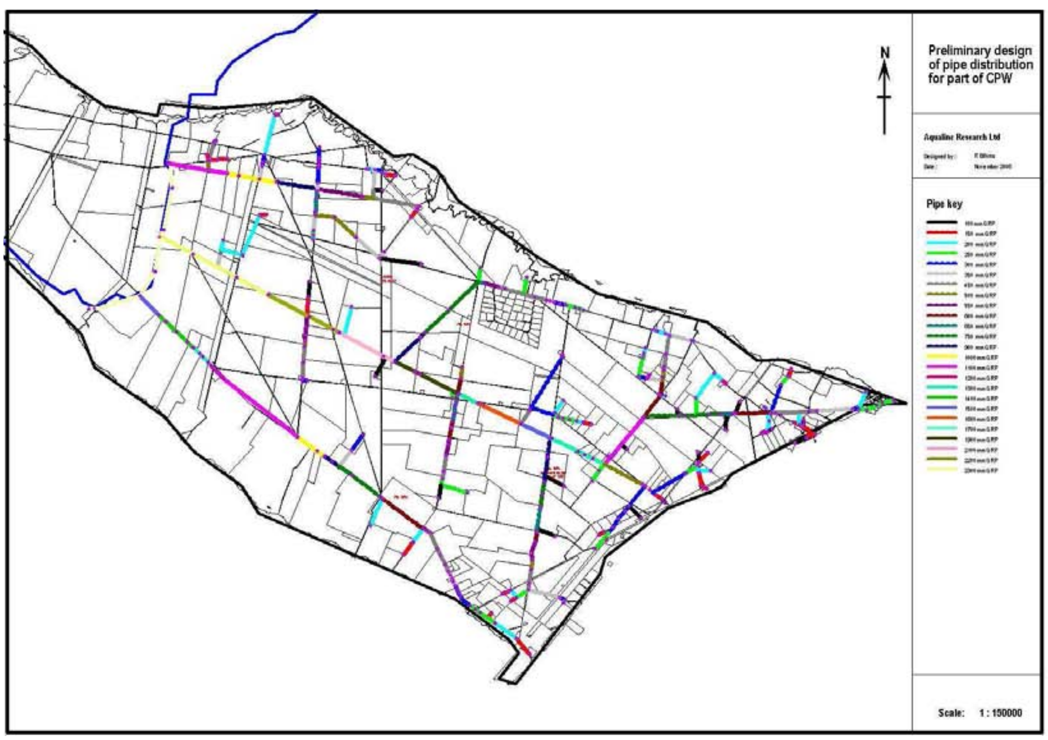



**Figure 1: CPW sub area pipe layout**

## *8.2 Preparatory Work*

This component covers all scheme evaluation, survey, design, contract preparation and building consent fees. The range considered appropriate is 4% to 8%.

## *8.3 Construction Management*

Contractors, designers and clients will be involved in contract management. Clients will often have the designer involved as the 'engineer to the contract' or for larger projects a specialist project manager may be employed. Modern schemes often employ professional staff or directors and these costs may be reflected in this component. We recommend a range of 4% to 6% for this component.

## *8.4 Primary Canal Offtakes*

These offtakes are unique to the proposed CPW primary canal. The cost of these items was taken from previous projects RILEY has been involved with. Photo 1 shows a similar offtake from a scheme currently under construction.

**Photo 1: Example of a typical primary headrace canal offtake structure under construction (2007)**

## *8.5 Primary Distribution Pipe*

Unit rates for pipes were supplied by Maskell Ltd, who manufacture and import fibre reinforced pipe (FRP), a 'fibreglass' pipe system. Pipe trench excavation was assumed to allow for 1 m of cover to the pipe crown so full farming of the land above the pipe could be achieved. Pipe bedding, haunch and backfill were assumed as processed from excavated trench materials and excess backfill crowned above the pipe excavation over a 15 m width.

At smaller diameters, HDPE, PVC and PE pipes were utilised as these materials are cheaper on a per unit rate installed.

No specific allowance was made for the pressure rating of the pipe as the variance of this cost was moderate when related to the total installed cost of the pipe. Figure 2 presents a best fit line for estimating the installed cost of a buried irrigation pipeline including excavation and backfill, bedding and haunch material, pipe. This figure was utilised for pricing.

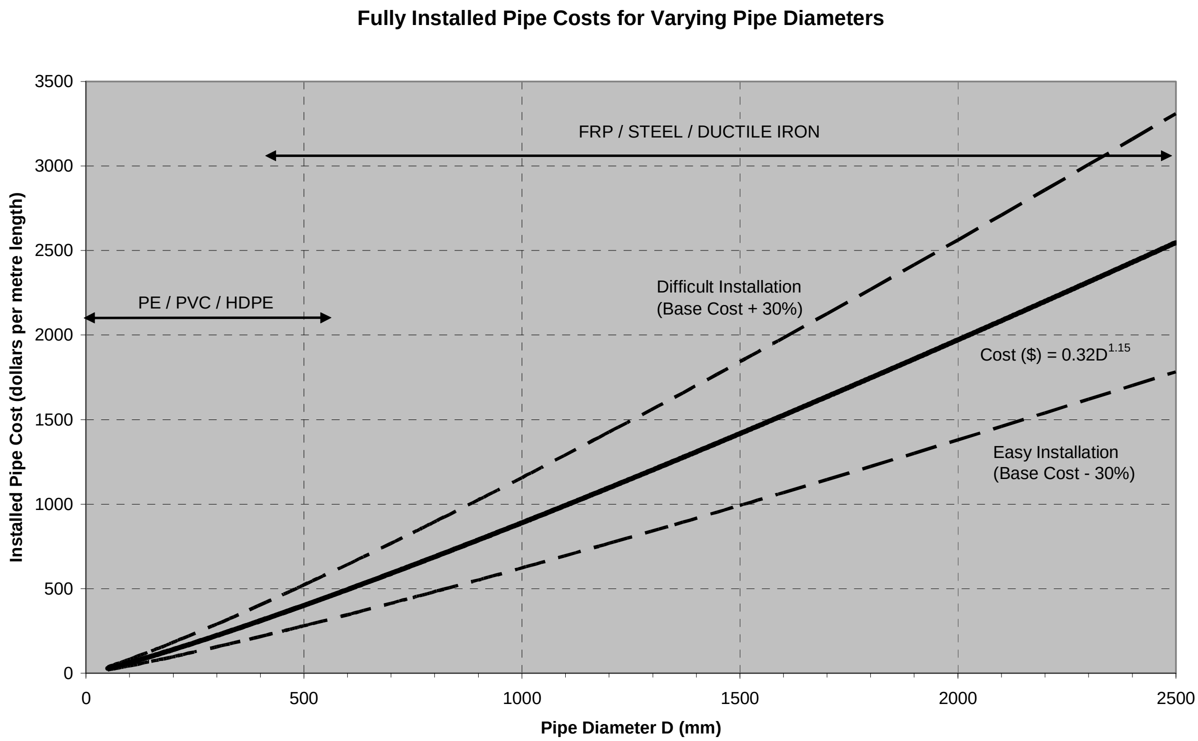



**Figure 2: Cost estimates for pipelines**

Photo 2 shows FRP pipe currently (2007) being installed in Otago (3000 m length).

**Photo 2: 1.1 m diameter FRP pipe (under construction 2007).**

## *8.6 Structures and Fittings*

This item includes air valves, flanges, bends, isolating valves, pressure control, drains and manholes, thrust blocks and road or stream crossings. Significant variation in this item can occur and is primarily dependant on topography and sit geology.

The CPW scheme covers an area of 'flat' land. Pipe lengths can therefore be long straights and soil friction can be used to carry longitudinal pipe loads. As there are minimal topographic changes, air relief valves costs will be significantly reduced. The cost component allowed for pipe fittings is at the lower end of the range for these reasons. Proposed schemes in undulating areas will require a higher percentage cost for these items.

In particular we utilize a range for additional items of:

- Flanges and bends – 7% to 17%
- All other items – 0.25% to 1%
- Overall range of 10% to 20% of installed pipe cost

**Photo 3: An FRP anchor block under construction (2007).**

### *8.7 Farm Offtakes*

The number and size of the offtakes was developed in the 'Irricad' model prepared by Aqualinc Ltd. Costs were supplied by Irrigation and Water Ltd of Christchurch (www.irrigationandwater.co.nz). Costs for these items included:

- Toby boxes
- Thrust supports
- Covers
- Valves
- Flow meters

## *8.8 Cost Estimate*

The total cost estimate for the scheme is $119,283,260 or $3,313.42/Ha. Note this does not make any allowance for ongoing maintenance or operation costs. A breakdown of the component costs estimated for the scheme are presented in Table 3.

**Table 3: CPW pipe cost.**

| | Item | Unit | Quantity | Rate | Total |
|---|---|---|---|---|---|
| 1 | **Preparatory work** | | | | |
| | Evaluation of service and farm liaison | LS | 1 | 0.50% | $549,202 |
| | Survey | LS | 1 | 0.20% | $219,681 |
| | Feasibility studies through final design | LS | 1 | 3.00% | $3,295,213 |
| | Contract Preparation and Tendering | LS | 1 | 0.50% | $549,202 |
| | Building Consent Fees | LS | 1 | 0.30% | $329,521 |
| | **Sub Total** | | | **4.50%** | **$4,942,820** |
| | | | | | |
| 2 | **Construction Management** | | | | |
| | Contractors Preliminary and General | LS | 1 | See note | $3,000,000 |
| | Construction management | LS | 1 | See note | $1,500,000 |
| | **Sub Total** | | | **4.10%** | **$4,500,000** |
| | | | | | |
| 3 | **Canal Offtakes** | | | | |
| | Civil Intake Structures | No | 3 | $350,000 | $1,050,000 |
| | Gates | No | 3 | $200,000 | $600,000 |
| | **Sub Total** | | | | **$1,650,000** |
| | | | | | |
| 4 | **Primary Distribution Pipe** | | | | |
| | Pipe Dia (mm) | | | | |
| | 90 | m | 10,000 | $ 57 | $573,833 |
| | 150 | m | 11,000 | $ 93 | $1,020,168 |
| | 200 | m | 17,300 | $ 125 | $2,161,116 |
| | 250 | m | 12,700 | $ 160 | $2,030,984 |
| | 300 | m | 14,500 | $ 197 | $2,851,715 |
| | 375 | m | 11,100 | $ 257 | $2,852,180 |
| | 450 | m | 14,000 | $ 323 | $4,518,955 |
| | 500 | m | 6,500 | $ 370 | $2,403,375 |
| | 600 | m | 12,100 | $ 471 | $5,700,068 |
| | 750 | m | 4,000 | $ 642 | $2,566,250 |
| | 800 | m | 9,500 | $ 703 | $6,681,540 |
| | 900 | m | 5,900 | $ 812 | $4,791,444 |
| | 1000 | m | 3,400 | $ 921 | $3,131,054 |
| | 1200 | m | 9,600 | $ 1,138 | $10,929,373 |
| | 1350 | m | 3,400 | $ 1,302 | $4,425,644 |
| | 1500 | m | 4,300 | $ 1,465 | $6,298,828 |
| | 1600 | m | 1,960 | $ 1,574 | $3,084,320 |
| | 1700 | m | 900 | $ 1,682 | $1,514,180 |
| | 1800 | m | 0 | $ 1,791 | $0 |
| | 1900 | m | 2,800 | $ 1,900 | $5,320,000 |
| | 2100 | m | 2,600 | $ 2,118 | $5,505,703 |
| | 2200 | m | 3,300 | $ 2,226 | $7,347,012 |
| | 2300 | m | 3,300 | $ 2,335 | $7,706,016 |
| | 2500 | m | | $ 2,553 | $0 |
| | **Scale Factor on pipe** | LS | 1 | 100.00% | $93,413,756 |
| | **Sub Total Pipe Cost** | | **164161** | | **$93,413,756** |
| | | | | | |
| 5 | **Structures and Fittings** | | | | |
| | Flanges and bends | LS | 1 | 7.50% | $7,006,032 |
| | Air valves | LS | 1 | 0.25% | $233,534 |
| | Isolating valves | LS | 1 | 0.25% | $233,534 |
| | Pressure Reducing Valves | LS | 1 | 0.50% | $467,069 |
| | Drain points and Manholes | LS | 1 | 0.25% | $233,534 |
| | Concrete thrust blocks and anchor blocks | LS | 1 | 0.25% | $233,534 |
| | Road and Stream crossings | LS | 1 | 0.50% | $467,069 |
| | **Sub Total** | | | **9.50%** | **$8,874,307** |
| | | | | | |
| 6 | **Farm Offtakes** | | | | |
| | 250mm diameter | No | 146 | $ 25,500.00 | $3,723,000 |
| | 200mm diameter | No | 35 | $ 18,000.00 | $630,000 |
| | 150mm diameter | No | 29 | $ 10,500.00 | $304,500 |
| | 100mm diameter | No | 23 | $ 8,300.00 | $190,900 |
| | 80mm diameter | No | 55 | $ 7,600.00 | $418,000 |
| | 50mm diameter | No | 19 | $ 6,600.00 | $125,400 |
| | **Sub Total** | | | | **$5,391,800** |
| | | | | | |
| 7 | **Misc** | | | | |
| | Fencing | LS | 10.00% | $11 | $180,577 |
| | Scheme control systems, power | No | 1 | $330,000 | $330,000 |
| | **Sub Total** | | | | **$510,577** |
| | | | | | |
| | **Total** | | | | **$119,283,260** |
| | **Irrigable Area** | Ha | | | 36,000 |
| | **Cost per hectare** | $/ha | | | $ 3,313.42 |

# 9.0 Case Study – CPW Open Channel Option

## *9.1 General Background*

Water is to be abstracted from the CPW headrace, and will be delivered to the proposed irrigable area via a primary and secondary open channel network developed by URS Ltd as a result of landholder and current consent discussions. The water will be delivered to each property using an off-take pond point (turnout) suitable for a pipe pumped offtake. A small area of the scheme is to be irritated by a small pipe network to avoid the need for a tertiary canal network.

Figure 3 presents the canal system layout for the CPW sub area.

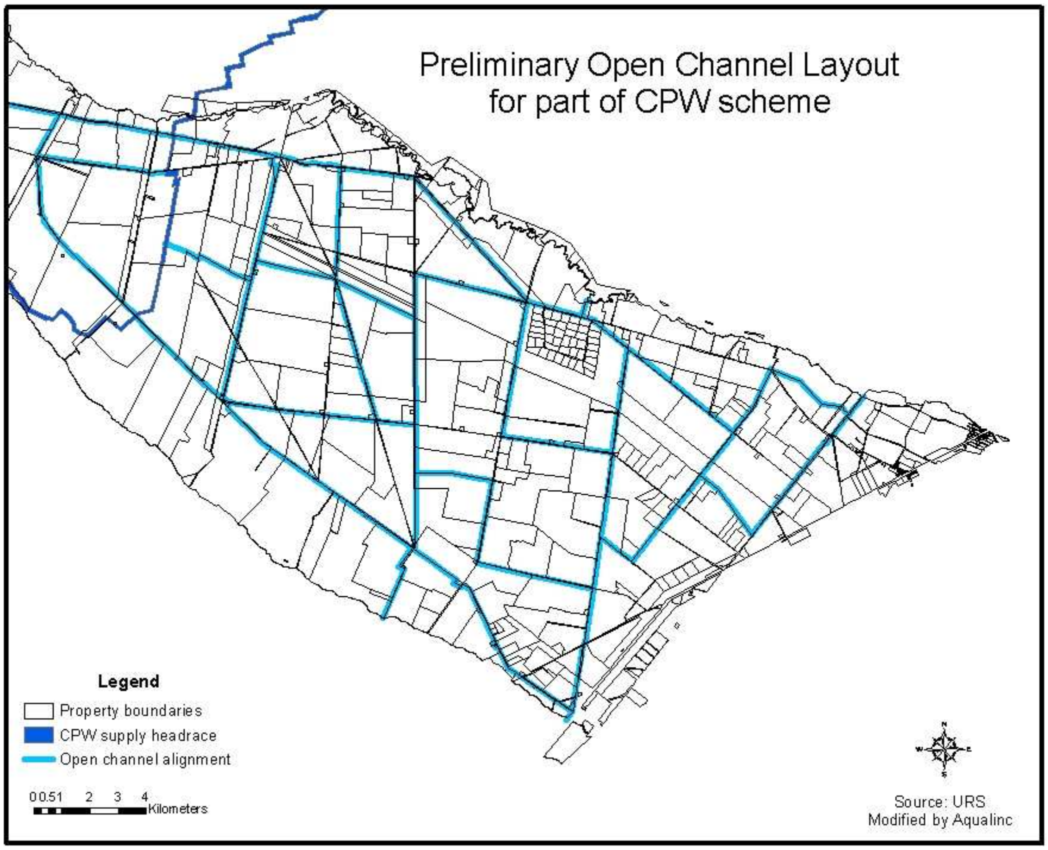



**Figure 3: CPW sub area canal scheme layout**

To irrigate all comparable land as with the CPW case pipe scheme study additional tertiary or pipe networks were required to achieve a comparable delivery and cost comparison. It was elected for minimal land disturbance that piping to farms for these small areas would be utilised for design. Figure 4 presents the canal scheme layout with sub catchment pipe areas to service all properties.

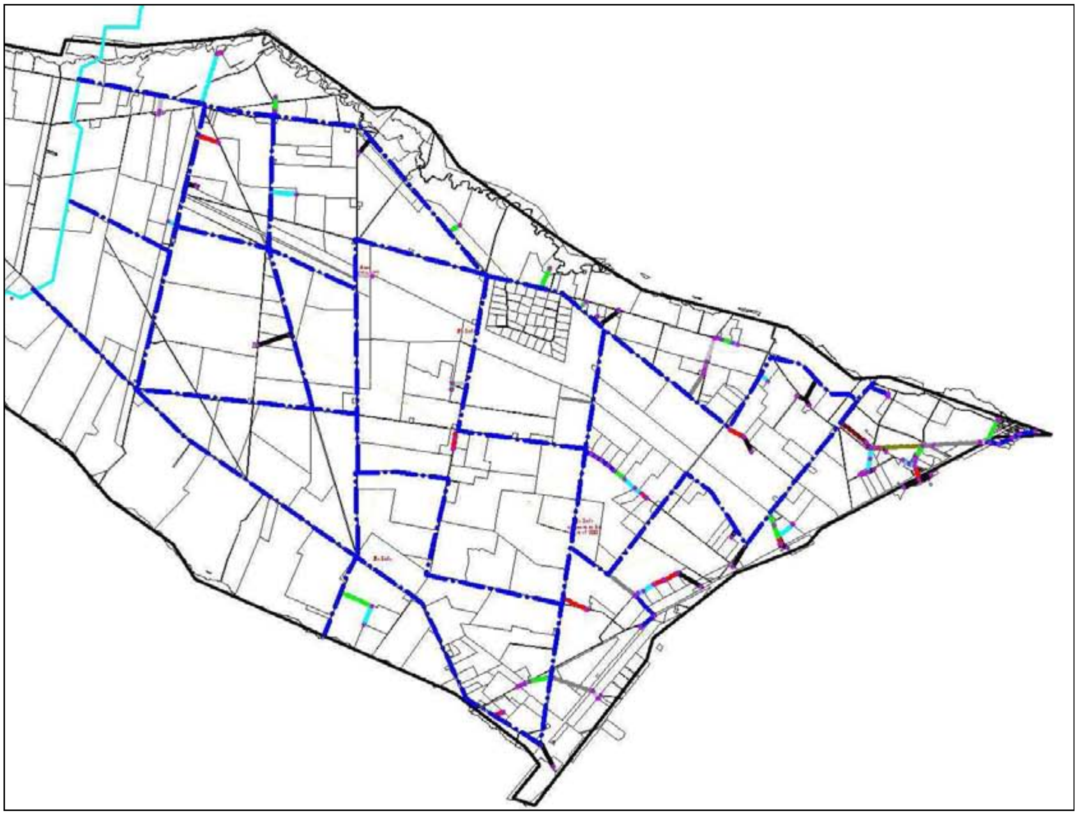
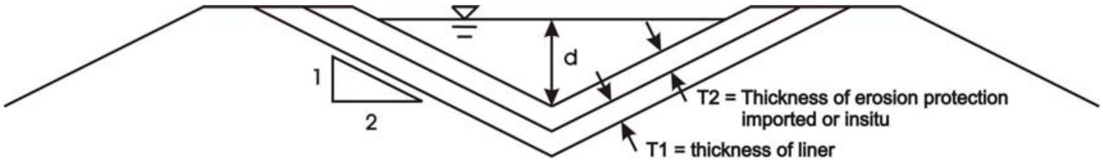


**Figure 4: Location of additional pipe to supply properties from the open race.**

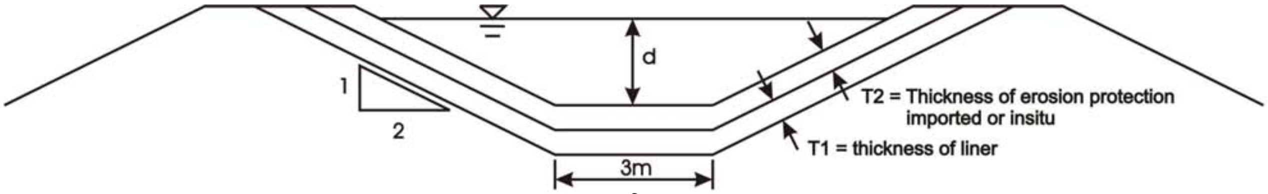
The following sections describe how costs were derived for the scheme area.

## *9.2 Canal Design Cross Sections*

Two different cross sections were designed to suit the required maximum flow rate of each canal section as shown on Figure 5 below. A triangular cross section was used for lengths of canal with flow rates of less than 2m$^3$/s. A trapezoidal profile was used for sections with canals with flow rates in excess of 2m$^3$/s. These two options were chosen from a construction perspective allowing for digger or grader excavation of small canals and for larger canal flow design sizings to allow economical construction by earth moving equipment.




Triangular cross section for flows less than 2m$^3$/s




Trapezoidal cross section for flows greater than $2m^3/s$

**Figure 5: Design canal cross sections utilised.**

## *9.3 Canal Layout*

The canal layout was developed by URS Ltd as shown in Figure 3. The following steps were then completed to develop the preliminary design to price:

- Code each canal section
- Determine canal section sizing based on canal gradients as assessed from 1:50,000 contours plans.
- Calculate erosion liner requirements based on canal velocities
- A each distribution point determine gate requirements
- Determine culverts for road crossings
- Develop a bill of quantities.

**Table 4: Canal network details for structures**

| Canal Code | Canal Flow | Length | Slope | Culverts Required | | Distribution Control gate | | |
|---|---|---|---|---|---|---|---|---|
| | m3/s | m | (1:~) | 900 mm | 1600 mm | Large | Medium | Small |
| L2B | 3.6 | 712 | 7119 | | | 1 | | |
| L3G | 6.3 | 3729 | 7458 | | 1 | 2 | | |
| L1E | 5.4 | 2847 | 5695 | | | 2 | | |
| L3D | 0.4 | 102 | 1017 | 1 | | | | 1 |
| L2J | 0.5 | 3797 | 759 | 1 | | | | 1 |
| L2G | 0.6 | 3966 | 793 | 1 | | | | 1 |
| L3N | 0.3 | 1932 | 483 | 1 | | | | 1 |
| L2C | 0.9 | 4407 | 630 | | | | 1 | |
| L2E | 0.6 | 4000 | 400 | 1 | | | | 1 |
| L2H | 0.6 | 5559 | 371 | 1 | | | | 1 |
| L3M | 0.7 | 8305 | 395 | 2 | | | | 1 |
| L3P | 3.5 | 813 | 813 | | | | | |
| L3K | 1 | 5288 | 353 | 3 | | | 1 | |
| L3J | 7 | 1864 | 932 | | 1 | 2 | | |
| L1G | 4.1 | 1695 | 565 | | | | | |
| L2K | 1.7 | 8814 | 367 | 1 | | | | |
| L3O | 2.8 | 6203 | 365 | | 1 | | | |
| L1I | 1.5 | 10000 | 222 | 2 | | | 1 | |
| L3I | 8 | 3050 | 610 | | 1 | | | |
| L2I | 1.3 | 5573 | 232 | 1 | | | 1 | |
| L3H | 2.5 | 4780 | 208 | | 3 | | 2 | |
| L1B | 8.4 | 373 | 373 | | 2 | | | |
| L1D | 3 | 5288 | 182 | | | 1 | | |
| L3L | 8.5 | 5424 | 339 | | 3 | | | |
| L1H | 2.6 | 2712 | 151 | 1 | | 1 | | |
| L2F | 1.8 | 2847 | 142 | 2 | | 1 | | |
| L2A | 4.5 | 4237 | 193 | | | 1 | | 1 |
| L2D | 3 | 2915 | 133 | | 1 | 1 | | |
| L1F | 3.6 | 1390 | 139 | | 2 | | | |
| L3Q | 16.5 | 339 | 339 | | | | | |
| L3F | 9 | 678 | 226 | | 1 | 2 | 1 | |
| L1K | 8 | 8678 | 202 | | 1 | | | |
| L3C | 9.2 | 8610 | 221 | | 3 | | | |
| L1C | 5.4 | 8746 | 146 | | 1 | 2 | | |
| L1J | 5.4 | 136 | 136 | | 1 | 2 | | |
| L1A | 7.5 | 4407 | 138 | | | 2 | | |
| L3E | 8.8 | 2068 | 148 | | | 4 | 2 | |
| L3B | 8.6 | 2407 | 142 | | 1 | | | |
| L3A | 8 | 3593 | 100 | | | 2 | | 1 |
| TOTAL | | 152284 | | 18 | 23 | 26 | 9 | 9 |

## *9.4 Canal Geology and Design Impacts*

No site-specific testing or investigation of the soil grading curves for design purposes was completed. As an initial assessment of the potential for erosion of the canal base and sides, typical practical size distribution curves for the materials anticipated on site were checked for erosion with the proposed canal gradients and water velocities. It was found that the local materials would likely erode at the URS proposed canal gradients and flow rates, and that specific gravel or cobble erosion protection measures would be required for many of the proposed canal sections.

For low gradients along the canal route (i.e. flatter than 1:400) it was assumed that the lining and armour material could be sourced on site. For steeper gradients the armour material would need to be imported.

Based on the above, a table of estimated per metre costs of earthworks and erosion protection was created for each canal flow and gradient.

## *9.5 Liner Material*

The URS Ltd design incorporates no liner material for seepage control. The RILEY preliminary design has concluded that a liner material is likely to be required. The thickness of both the liner and erosion protection (T1 and T2 on Figure 5) was assumed to be 0.5 m. Cost estimates for lining and erosion protection were then derived for steep and flatter canal gradients as shown on Table 5.

**Table 5: Cost applied for erosion protection and liner**

| Canal Grade | Cost Erosion protection | Liner (Available on site) |
|---|---|---|
| Low Gradient ( flatter than around 1:400 ) | \$ 3 / $m^3$ (Site erosion protection) | \$10 / $m^3$ |
| Steep Gradient ( steeper than around1:400 ) | \$20 / $m^3$ (Imported erosion protection) | \$10 / $m^3$ |

Table 6 is a summary of the average cost of the liner, erosion protection and earthworks for different canal conditions as defined above.

**Table 6: Average cost for different canal conditions**

| Canal Type | Total Length (m) | Liner and Erosion Protection (\$/m) | Earthworks (\$/m) | Total (\$/m) |
|---|---|---|---|---|
| Steep Gradient Canal 1 to 3.5 $m^3$/s | 50522 | \$150 | \$30 | \$180 |
| Steep Gradient Canal 3.5 to 9.2 $m^3$/s | 54440 | \$181 | \$74 | \$255 |
| Low Gradient Canal 0.3 to 1 $m^3$/s | 37356 | \$52 | \$15. | \$67 |
| Low Gradient Canal 3.5 to 9.2 $m^3$/s | 9966 | \$91 | \$136 | \$227 |

## *9.6 Intake Structures*

The main canal offtakes are proposed as structures penetrating a canal embankment with energy dissipation at the end. Photo 4 shows an offtake structure suitable for the CPW sub area under constructed in 2007.


**Photo 4: Offtake drop structure.**

## *9.7 Road Crossing and Culverts*

The number of road crossings was estimated from existing maps and a plan of the proposed scheme extensions. Preliminary culvert diameters were calculated based on the required maximum flow at each road crossing. Prices for crossings were based on similar structures currently under construction.

## *9.8 Distribution Control Gates*

Control gates are required at nodes where a single canal divides to service two or more separate areas. The number of nodes requiring control gates was obtained from the proposed scheme extension plan as shown on Figure 1. Per unit costs were obtained for three automated Rubicon Flume Gates gate sizes to suit the required flow rate at each node. The Rubicon gates are fully automated and include flow gauging. Full details of the Rubicon gates can be obtained at the web site www.rubicon.com.au. Photo 5 presents a series of Rubicon gates being installed.


**Photo 5: Rubicon gates under construction.**

## *9.9 Drop Structures*

Only one drop structure was required on a particularly steep canal section. Photo 6 Shows a USBR Type 2 drop structure for a 2.5 cumec flow constructed in 2007.

**Photo 6: Drop Structure**

## *9.10 Cost Estimate*

The total cost estimate for the scheme is $62,404,533 or $1,733/Ha. Note this does not make any allowance for ongoing maintenance or operation costs. A breakdown of the component costs estimated for the scheme are presented in Table 7.

**Table 7: Cost estimate for CPW sub area canal network**

| | Item | Unit | Quantity | Rate | Total |
|---|---|---|---|---|---|
| 1 | **Preparatory work** | | | | |
| | Evaluation of service and farm liaison | LS | 1 | 1.25% | $677,970 |
| | Survey | LS | 1 | 0.50% | $271,188 |
| | Feasibility studies through final design | LS | 1 | 4.50% | $2,440,692 |
| | Contract Preparation and Tendering | LS | 1 | 1.00% | $542,376 |
| | Building Consent Fees | LS | 1 | 0.30% | $162,713 |
| | **Sub Total** | | | 7.55% | **$4,094,939** |
| | | | | | |
| 2 | **Construction Management** | | | | |
| | Contractors Preliminary and General | LS | 1 | 6% | $2,714,660 |
| | Construction management | LS | 1 | See note | $1,357,330 |
| | **Sub Total** | | | | **$4,071,991** |
| | | | | | |
| 3 | **Primary Canal Offtakes** | | | | |
| | Civil Intake Structures incl gates | No | 3 | $ 450,000.00 | $1,350,000 |
| | **Sub Total** | | | | **$1,350,000** |
| | | | | | |
| 4 | **Primary Distribution Canals** | | | | |
| | Low gradient canal 0.3 to 1 cumec capacity | m | 37356 | $ 90.00 | $3,362,040 |
| | Low gradient canal 3.5 to 9 cumec capacity | m | 9966 | $ 130.00 | $1,295,580 |
| | | | | | |
| | High gradient canal 1 to 3.5 cumec capacity | m | 50522 | $ 170.00 | $8,588,740 |
| | High gradient canal 3.5 to 9 cumec capacity | m | 54440 | $ 200.00 | $10,888,000 |
| | **Sub Total** | | | | **$24,134,360** |
| | | | | | |
| 5 | **Additional Distribution Pipe ( to properties not adjacent to race)** | | | | |
| | Pipe Dia (mm) | | | | |
| | 100 | m | 8720 | $ 57 | $500,354 |
| | 150 | m | 5150 | $ 93 | $477,611 |
| | 200 | m | 7500 | $ 125 | $936,900 |
| | 250 | m | 6740 | $ 160 | $1,077,861 |
| | 300 | m | 4920 | $ 197 | $967,616 |
| | 350 | m | 2800 | $ 257 | $719,460 |
| | 450 | m | 5330 | $ 323 | $1,720,417 |
| | 500 | m | 1580 | $ 370 | $584,205 |
| | 600 | m | 1250 | $ 471 | $588,850 |
| | **Sub Total** | | **43990** | | **$7,573,274** |
| | | | | | |
| 6 | **Pipe Fitting** | | | | |
| | Flanges and bends | LS | 1 | 15.00% | $1,135,991 |
| | Air valves | LS | 1 | 0.50% | $37,866 |
| | Isolating valves | LS | 1 | 0.50% | $37,866 |
| | Drain points and Manholes | LS | 1 | 0.75% | $56,800 |
| | Concrete thrust blocks and anchor blocks | LS | 1 | 1.00% | $75,733 |
| | Road and Stream crossings | LS | 1 | 1.00% | $75,733 |
| | **Sub Total** | | | **18.75%** | **$1,419,989** |
| | | | | | |
| 7 | **Structures and Fittings** | | | | |
| | Control Gate – Small | No | 9 | $ 33,000.00 | $297,000 |
| | Control Gate – Medium | No | 12 | $ 50,000.00 | $600,000 |
| | Control Gate – Large | No | 17 | $ 90,000.00 | $1,530,000 |
| | Road crossing culvert 0.9m diameter | No | 21 | $ 14,000.00 | $294,000 |
| | Road crossing culvert 1.6m diameter | No | 20 | $ 80,000.00 | $1,600,000 |
| | Small on-farm bridge crossings | No | 75 | $ 25,000.00 | $1,875,000 |
| | Additional large Riprap in locally steepened areas and around structures | $m^3$ | 12000 | $ 80.00 | $960,000 |
| | Bywash with energy dissipation to river discharge | No | 4 | $ 100,000.00 | $400,000 |
| | **Sub Total** | | | | **$7,556,000** |
| | | | | | |
| 8 | **Farm Offtakes** | | | | |
| | Off-canal stilling bay and coarse screen | No | 237 | $ 12,000.00 | $2,844,000 |
| | Small drop structures for water level raising at gates | No | 119 | $ 5,000.00 | $592,500 |
| | 250mm diameter | No | 146 | $ 25,500.00 | $3,723,000 |
| | 200mm diameter | No | 35 | $ 18,000.00 | $630,000 |
| | 150mm diameter | No | 29 | $ 10,500.00 | $304,500 |
| | 100mm diameter | No | 23 | $ 8,300.00 | $190,900 |
| | 80mm diameter | No | 55 | $ 7,600.00 | $418,000 |
| | 50 mm diameter | No | 19 | $ 6,600.00 | $125,400 |
| | **Sub Total** | | | | **$8,828,300** |
| | | | | | |
| 9 | **Misc** | | | | |
| | Fencing | m | 304568 | $ 10.00 | $3,045,680 |
| | Scheme control systems and telecoms | LS | 1 | $ 330,000.00 | $330,000 |
| | **Sub Total** | | | | **$3,375,680** |
| | | | | | |
| | **Total** | | | | **$62,404,533** |
| | **Irrigable Area** | Ha | | | 36,000 |
| | **Cost per hectare** | $/ha | | | $1,733 |

# 10.0 Case Study – Ashburton Lyndhurst Sub Area Pipe Scheme

The following sections document assumptions and methods used for a preliminary cost estimate for part of the Rangitata Diversion Race (RDR) Irrigation Scheme. The area under consideration contains 3,200 hectares of irrigable land. The ground surface is similar to that considered for the CPW sub area, comprising a gently sloping alluvial terrace. Subsurface conditions are expected to comprise free-draining gravels overlain by a variable thickness of silty gravel and topsoil. The distance between the offtake at the RDR and the farthest extent of the area considered is approximately 190m vertical height and 25km horizontal distance.

No site visits, survey, ground investigations, or detailed design checks have been undertaken to produce this cost estimate. Published maps, property boundaries and regional geological plans for the area have been reviewed and applicable information incorporated where appropriate.

The area under consideration already has a functioning canal-based irrigation scheme. The motivation for assessment of a piped alternative includes elimination of seepage losses and supply of full or partial pressure at irrigation offtakes. The preliminary layout of the piped distribution scheme has been developed by Aqualink Research Ltd utilising “Irricad” pipe network design software.

## *10.1 General Background*

The following notes describe features of the Ashburton Lyndhurst Sub Area Pipe Scheme that affected how the price estimate for the scheme was developed.

- The scheme already possesses a functioning primary canal between the Rangitata and Rakaia Rivers. Significant intake work, fish screens or river training are not accounted for.
- The topography is generally flat when compared to other parts of New Zealand. The pipe layout does not involve complicated plan or elevation changes which can significantly affect costs of trenching, bend manufacture and thrust blocks.
- Groundwater into the trench excavation is not considered significant.
- The land is primarily cleared farmland.
- The majority of item estimates are based on unit rates as pre-feasibility level design has not been completed. Several suppliers were contacted for input. Pipe unit costs (the largest component) were developed from first principals.
- The scheme did not run along existing irrigation races. The layout was optimized for pipe cost minimisation.
- The existing race alignment would be infilled after pipe construction and returned to productive farm land.

The scheme layout is shown in Figure 6.

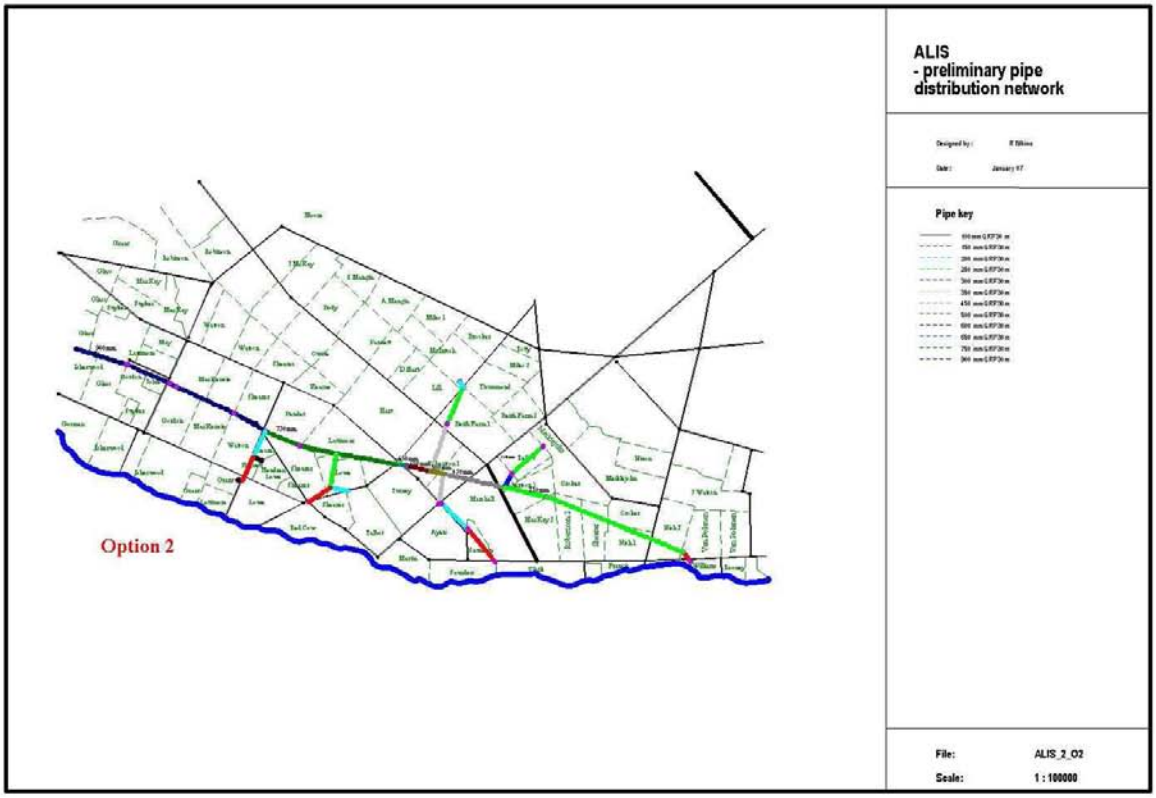



**Figure 6: ALIS sub area pipe scheme.**

## *10.2 Preparatory Work*

This component covers all scheme evaluation, survey, design, contract preparation and building consent fees. The range considered appropriate is 4% to 8%.

## *10.3 Construction Management*

Contractors, designers and clients will be involved in contract management. Clients will often have the designer involved as the 'engineer to the contract' or for larger projects a specialist project manager may be employed. Modern schemes often employ professional staff or directors and these costs may be reflected in this component. We recommend a range of 4% to 6% for this component.

## *10.4 Primary Canal Offtakes*

The cost of these items was taken from previous projects RILEY has been involved with.

Unit rates for pipes were supplied by Maskell Ltd, who manufacture and import fibre reinforced pipe (FRP), a 'fibreglass' pipe system. Pipe trench excavation was assumed to allow for 1 m of cover to the pipe crown so full farming of the land above the pipe could be achieved. Pipe bedding, haunch and backfill were assumed as processed from excavated trench materials and excess backfill crowned above the pipe excavation over a 15 m width. Pipe values from Figure 2 were utilised for pricing.

At smaller diameters, HDPE, PVC and PE pipes were utilised as these materials are cheaper on a per unit rate installed.

No specific allowance was made for the pressure rating of the pipe as the variance of this cost was moderate compared to the total installed cost of the pipe. These pipes were routed for the shortest length rather than skirting around properties or roads.

## *10.5 Structures and Fittings*

This item includes air valves, flanges, bends, isolating valves, pressure control, drains and manholes, thrust blocks and road or stream crossings. Significant variation in this item can occur and is primarily dependant on topography and sit geology.

The ALIS scheme covers an area of 'flat' land. Pipe lengths can therefore be long straights and soil friction can be used to carry longitudinal pipe loads. In addition, as there are minimal topographic changes and air relief valves etc will be significantly reduced. The percentage figures given are considered to be at the lower end of the estimate from the above reasons. Proposed schemes in undulating or topographically challenging areas will require a higher percentage cost for these items.

In particular we utilize a range for additional items of:

- Flanges and bends – 7% to 17%
- All other items – 0.25% to 1%
- Overall range of 10% to 20% of installed pipe cost

## *10.6 Farm Offtakes*

The number and size of the offtakes was developed in the 'Irricad' model prepared by Aqualine Ltd. Costs were supplied by Irrigation and Water Ltd of Christchurch. Costs for these items included:

- Toby boxes
- Thrust supports
- Covers
- Valves
- Flow meters

## *10.7 Cost Estimate*

The total cost estimate for the scheme is $12,864,732 or $4,020.23 /Ha. Note this does not make any allowance for ongoing maintenance or operation costs. A breakdown of the component costs estimated for the scheme are presented in Table 8.

**Table 8: Cost estimate for CPW sub area canal network.**

| | Item | Unit | Quantity | Rate | Total |
|---|---|---|---|---|---|
| **1** | **Preparatory work** | | | | |
| | Evaluation of service and farm liaison | LS | 1 | 0.00% | $0 |
| | Survey | LS | 1 | 0.50% | $58,244 |
| | Feasibility studies through final design | LS | 1 | 3.00% | $349,463 |
| | Contract Preparation and Tendering | LS | 1 | 0.50% | $58,244 |
| | Building Consent Fees | LS | 1 | 0.00% | $0 |
| | **Sub Total** | | | **4.00%** | **$465,951** |
| | | | | | |
| **2** | **Construction Management** | | | | |
| | Contractors Preliminary and General | LS | 1 | See note | $500,000 |
| | Construction management | LS | 1 | See note | $250,000 |
| | **Sub Total** | | | **6.44%** | **$750,000** |
| | | | | | |
| **3** | **Canal Offtakes** | | | | |
| | Civil Intake Structures | No | 1 | $100,000 | $100,000 |
| | Gates | No | 0 | $0 | $0 |
| | **Sub Total** | | | | **$100,000** |
| | | | | | |
| **4** | **Primary Distribution Pipe** | | | | |
| | Pipe Dia (mm) | | | | |
| | 90 | m | 350 | $ 57 | $20,084 |
| | 150 | m | 2,640 | $ 93 | $244,840 |
| | 200 | m | 2,220 | $ 125 | $277,322 |
| | 250 | m | 7,720 | $ 160 | $1,234,582 |
| | 300 | m | 460 | $ 197 | $90,468 |
| | 375 | m | 1,990 | $ 257 | $511,337 |
| | 450 | m | 1,540 | $ 323 | $497,085 |
| | 500 | m | 330 | $ 370 | $122,018 |
| | 600 | m | 890 | $ 471 | $419,261 |
| | 750 | m | 3,360 | $ 642 | $2,155,650 |
| | 800 | m | | $ 703 | $0 |
| | 900 | m | 5,140 | $ 812 | $4,174,241 |
| | **Scale Factor on pipe** | LS | 1 | 100.00% | $9,746,889 |
| | **Sub Total Pipe Cost** | | **26641** | | **$9,746,889** |
| | | | | | |
| **5** | **Structures and Fittings** | | | | |
| | Flanges and bends | LS | 1 | 7.50% | $731,017 |
| | Air valves | LS | 1 | 0.25% | $24,367 |
| | Isolating valves | LS | 1 | 0.25% | $24,367 |
| | Pressure Reducing Valves | LS | 1 | 0.50% | $48,734 |
| | Drain points and Manholes | LS | 1 | 0.25% | $24,367 |
| | Concrete thrust blocks and anchor blocks | LS | 1 | 0.25% | $24,367 |
| | Road and Stream crossings | LS | 1 | 0.25% | $24,367 |
| | **Sub Total** | | | **9.25%** | **$901,587** |
| | | | | | |
| **6** | **Farm Offtakes** | | | | |
| | 250 mm diameter | No | 7 | $ 25,500.00 | $178,500 |
| | 200 mm diameter | No | 7 | $ 18,000.00 | $126,000 |
| | 150 mm diameter | No | 5 | $ 10,500.00 | $52,500 |
| | 100 mm diameter | No | 6 | $ 8,300.00 | $49,800 |
| | 80 mm diameter | No | 1 | $ 7,600.00 | $7,600 |
| | 50 mm diameter | No | 1 | $ 6,600.00 | $6,600 |
| | **Sub Total** | | | | **$421,000** |
| | | | | | |
| **7** | **Misc** | | | | |
| | Fencing | LS | 10.00% | $11 | $29,305 |
| | Scheme control systems, power | No | 1 | $50,000 | $50,000 |
| | Infill canal | LS | 1 | $400,000 | $400,000 |
| | **Sub Total** | | | | **$479,305** |
| | | | | | |
| | **Total** | | | | **$12,864,732** |
| | **Irrigable Area** | Ha | | | 3,200 |
| | **Cost per hectare** | $/ha | | | $ 4,020.23 |

## *10.8 Cost Sensitivity*

Assessing the risk appetite that developers of a scheme are willing to accept can significantly affect the price paid for construction; operation and maintenance costs; and the replacement period between parts of the scheme infrastructure as it wears out. Risk is not discussed in detail in this report, but an inherent assumption is made that developers will assess it at all levels and for all components of a scheme whether specifically, or by intuition in the decision making process.

To assess the influence of RISK and decision making, the ALIS case study was subject to a second phase of pricing to determine if capital cost could be reduced by altering RISK assumptions. The focus was to reduce the costs given in section 10.8. The following lists altered assumptions for assessing the revised costs.

- There is minimal design and a larger portion of 'contractor' design is utilized.
- A small contractor is utilized
- A simple form of contract is used with even risk sharing
- The project is not tendered
- There is a significant portion of the project management undertaken by the scheme developers and the contractor.
- Cheaper pipe materials are utilised, PE in place of FRP.
- Fencing and infilling of the canal for example are not undertaken.

The construction price calculated was approximately $8,500,000 m or $2656/ha. The price was cross checked and confirmed by a contractor. The revised price is approximately 35% lower than that given in Table 8 and comparable to the 30% estimated variation in price estimates expected as presented in Section 8.5.

## *10.9 Cost Sensitivity*

Assessing the risk appetite that developers of a scheme are willing to accept can significantly affect the price paid for construction; but also it can significantly affect operation and maintenance costs, and the replacement period for parts of the scheme infrastructure as it wears out. Risk is not discussed directly in this report, but an inherent assumption is made that it will be.

To assess the influence of RISK and decision making the ALIS case study was subject to a second phase of pricing to determine if capital cost could be reduced by altering RISK assumption. The focus was to reduce costs given in section 10.8. The following lists altered assumptions.

- The project is not tendered
- There is minimal design and a larger portion of 'contractor' design is utilized.
- A small contractor is utilized
- There is a significant portion of the project management undertaken by the scheme developers.
- Cheaper pipe materials are used, PE in place of FRP.

- Fencing and infilling of the canal are not undertaken.

The construction price obtained was $8.5 m or $2656/ha. The price was checked and confirmed by a contractor. The revised price is approximately 35% lower and comparable to the 30% estimated variation presented in section 8.5.

# 11.0 Lessons Learned From Case Studies

## *11.1 General Cost Estimation*

- The accuracy of cost estimation and reliance put on values should be reflective of the level of investigation or design the scheme is at.
- In early stage investigations scheme costs are underestimated. Often hidden costs and requirements are only considered at later stages.
- A number of unexpected costs often become exposed in detailed design.
- Effort to complete several design iterations is recommended to optimise schemes as significant savings can be made with efficient designs.
- The method of 'contract' with contractors affects scheme cost. Contracts are a risk sharing device and the more risk a contractor takes the greater the cost.
- Suppliers and contractors are often willing to assist with pricing components of projects.

## *11.2 Piped Schemes*

- Pipe scheme cost is generally similar nation wide dependent on pipe material utilized. Alternative pipe types often come with specialized installation systems that have comparable final installed costs.
- For large schemes, often effort is put into sourcing materials from less expensive countries with minimal representation in New Zealand. Experience indicates the cost of pipes made outside New Zealand is not significantly cheaper than local products for comparable material properties. Low quality pipes can be sourced internationally (up to 50% cheaper) but carry a corresponding risk factor.
- Pipe sizes less than 600 mm can often utilize several material types. Above 600 mm the range of materials is more limited including supplier choice. Optimising pipe diameter during design can save significant costs.
- The pipe scheme case studies will provide an approximate scheme cost independent of scheme location in New Zealand. The spreadsheet was developed for gravity water supply at the intake. Pump schemes may alter pipe designs based on transient effects and the velocity versus friction loss design of the pipe.
- For schemes with frequent topographic variation a significant proportional cost will be bends and anchor blocks.
- Contractors for pipe scheme construction is limited when compared to canal construction due to specialist skills often required, such as ticketed welding or installation techniques.
- The layout of the scheme significantly affects costs. Long large diameter primary

feeder pipes should be minimized. The two case studies highlighted that the overall scheme layout affects the efficiency of the design.

## *11.3 Open Channel Schemes*

- Canal scheme design is typically unique to the location and flow requirements, and unit costs are not easily transferred from one scheme to another.
- Local geology, topography and intake locations significantly alter the infrastructure design.
- The acceptance criterion for water losses requires consideration by developers and the appropriate Resource Consenting authority. Where seepage targets are set without regard to the available soil types and construction materials canal lining may become prohibitively expensive or possible unfeasible from a technical viewpoint. Lining costs are a large portion of canal costs.
- Contractors and equipment for canal scheme construction are readily available and competitive prices can be obtained for construction.
- For larger canal schemes it may be appropriate to pipe smaller sub areas of the scheme rather than constructing tertiary canal systems.
- Water management of canal schemes is often more wasteful than pipe schemes. Utilising modern control systems and equipment such as automated gates for a new scheme will provide significantly improved water usages tan a manual system.

# APPENDIX 6
# BASIS OF ECONOMIC COST COMPARISONS

# Contents

# BASIS OF ECONOMIC COST COMPARISONS

## 1.0 Purpose

The purpose of this Appendix is twofold: (a) to describe, in generic terms, a methodology to compare piped vs. open channel irrigation distribution networks from an economic perspective; and (b) to present the results of applying the methodology to the two case study investigations.

The Appendix first addresses some conceptual issues, and then lays out a comparative framework. The application of the methodology to the case studies is presented in the last sections, along with a description of the assumptions used in developing estimates of non-capital costs, and the results of the economic cost comparisons.

## 2.0 Conceptual Issues

There are two possible capital-works scenarios which are discussed in this Appendix – (i) where piped vs. open channel networks are to be compared in a "greenfields" development situation; and (ii) where an open-channel distribution network is currently part of an operational irrigation scheme, and "retrofitting" is envisaged to replace the open channel network with a pressurised pipe reticulation system. The principles underlying an economic evaluation are similar in both cases.

Firstly, it can usually be assumed that the gross, per hectare farm benefits from spray irrigation under either scenario are the same[1]. The key issue for evaluating the two "greenfields" options is to determine the most economically efficient way to supply this water to the farm – either through a network of open channels delivering water to farm turnouts; or through network of pipes delivering the same volume of water at variable pressures (according to turnout location and time), so reducing the need for on-farm pressurization with associated electricity costs, and reducing system water losses. The aim of the evaluation is therefore to compare the total costs of the two options – acknowledging that some of the items included as costs may not be able to be valued in "dollar" terms[2]. For a greenfields site, the piped system will involve greater capital costs than the open-channel system, but this will be partially offset by savings in on-going operations and maintenance costs given that the piped system will supply pressurized water at the farm turnouts. In addition, the piped system will minimise water losses through the distribution network, and result in water savings which means lower water volumes abstracted by the scheme. The preferred

[1] This assumption may not apply in certain circumstances.

[2] For example, an open channel network may be able to direct by-wash into an associated wetlands area generating positive environmental values which are difficult to monetise.

evaluative approach is therefore to compare the cost differences between the two systems calculating the extent to which the savings in operations and maintenance costs with the piped system (largely through savings in electricity costs) together with the value of water savings, offset the higher capital costs associated with a piped network. Other items (costs or benefits) will also vary between the two options and need quantification where possible.

For the retrofitting option, the comparison is similar, except the objective is to compare the costs associated with continuing the status quo, compared with the costs (both capital and on-going) of retrofitting the system with a piped distribution system. In this case, piping will involve initial capital costs, which will be offset by the savings in electricity pumping costs (since the piped system will deliver pressurized water to the farm turnout), as well as the value of the water savings resulting from the piped system (equivalent to the losses from the existing open channel network). In addition, there will be other considerations to be taken into account, some of which will have a monetary value and some not[3].

The costs items are usually quantified in current prices, so all the costs have the same price datum (such as June 2006). Although most prices will be maintained relative to each other over the life of the analysis period, some relative prices may change due to real price increases – an example of this is the unit price for electricity which many commentators expect will, over the near future, increase faster than the level of inflation. This “real” price increase should be incorporated into the analysis. Similarly, where some prices are dependent on the foreign exchange cross rate to a particular currency (for example, pumps imported from the United Sates), then it is also important to consider how prices might change over the analysis period should the cross rate adjust from what was assumed at the price datum.

Data estimates for costs should be projected over the period of the analysis, and this period needs to be relatively long – probably around 20-30 years – to truly reflect the relative cost differences between the options being evaluated. These cost streams, all at the assumed price datum, need to be “discounted” to a present-value equivalent to assess which option is financially preferable. The results can be subjected to sensitivity analysis to demonstrate the effects of changing the discount rate – for example, real rates between 6 and 10 percent would seem appropriate at present.

As noted above, however, all differences between the options being assessed will not necessarily lend themselves to financial quantification – some items may have “environmental” values which are difficult to quantify. The decision framework will therefore incorporate both financial and non-financial decision criteria.

## 3.0 Considerations

The following paragraphs detail the individual items that need to be considered in the analysis. The text is written from the perspective of a comparative analysis of a new, greenfields development which has either open-channel or piped reticulation network options, but is equally applicable to a retrofit scenario with some modification.

[3] For example, an existing open channel network may direct by-wash into an associated wetlands area. Such wetlands may have positive environmental value. Where this open-channel network is to be replaced with a pressurized pipe system this value would be lost, but it may be difficult to quantify this “cost” in monetary terms

### *3.1 Capital Costs.*

The Appendix on Costs (Appendix 5), details the itemised capital costs required for estimating open channel and piped reticulation networks. Pre-construction costs will also need to be included, covering such items as feasibility studies through to final design, contract preparation and tendering, liaison with stakeholders, resource consent and building consent costs, legal fees, etc. These are also described in this Appendix, although some individual items merit separate mention:

### *3.2 Easement Costs.*

It can be assumed that the main, open channel reticulation network will principally run parallel to the existing road network, whereas the piped system, which will be buried at least 1m underground, will be trenched in the most direct routing across farm land with no subsequent adverse impact on farm operations. Formal, legal easements will be required for both scenarios, but the legal costs with creating the easements associated with the pipe network are likely to be less than those associated with the open-channel network, given the lower complexity of the former[4].

### *3.3 Access Costs.*

Where open channels need to cross existing farm land, there will be an impact on access and accessibility, which is only partly defrayed with culvert crossings. While compensation will be paid to farmers affected through purchase of this land, and this compensation will include injurious affects (such as impact on on-farm management and costs), there is little doubt that the piped reticulation system will minimise these effects. In addition it should be noted that land use flexibility may be reduced with an open channel system in that future re-organisation of farm plots and paddocks may be hindered by the network of open channel races, a constraint not imposed with an underground, piped reticulation system.

### *3.4 Land Purchase Costs.*

It is probable that all private land involved in the footprint corridor for an open channel distribution system will need to be purchased by the scheme developer/operator[5].

[4] Survey costs associated with the piped distribution system are also likely to be less than with the open channel network, for similar reasons.

[5] Although some channels will run parallel to the road network, the width of these corridors will mean that typically the width of existing road reserve margins will be too small to accommodate the channels (given road safety requirements) and purchase of adjacent land will be necessary.

### *3.5 Infrastructure Costs.*

Depending on the existing capacity of the electricity network serving the area, it is possible that network upgrading will be required principally to cater for the increased load factors associated with on-farm irrigation pumps. In a situation with a piped supply, and where a significant proportion of water is delivered to the farm turnout under pressure, pumping demands will be reduced and the extent of the upgrades (if any) required to the electricity network serving the area may be also reduced (depending on a number of technical factors such a peak capacity and instant load factors).

### *3.6 System Operational Costs.*

Each system will also have associated operations (covering system operation and control) and maintenance costs – regular maintenance (say annually), periodic maintenance (say once every five years), and extraordinary maintenance (relating to response to extraordinary events such as major floods, power outages, or earthquakes).

### *3.7 On-Farm Pumping Costs.*

Each option will have associated on-farm pumping costs. The open channel system will deliver water at zero head to the farm turnout, and all irrigation water applied will require pumping. Depending on the topography of the command area (particularly the fall from the headrace), location of the turnout within the scheme, and the demands on the system, the piped system will be able to deliver pressurised water at the turnout, which will negate the need to all or part of the on-farm pumping costs associated with the open channel system. The extent of these “savings” will be site specific, as discussed later in this Appendix.

### *3.8 Water Savings.*

The piped reticulation network will have the ability to deliver pressurized water at the farm turnout (so reducing subsequent pumping costs for the on-farm irrigation units), as well as generating water system savings when comparing open channel vs. piped reticulation networks. Water losses in an open channel reticulation network depend on a number of factors (such as the permeability of the channel prism), and can be of the order of 10-30 percent of the water delivered into the network. Given that losses in the piped system will be zero, these water savings can have a significant value – (i) creating the ability to irrigate more area on existing farms through increasing the volumes supplied to individual turnouts; (ii) allowing “extra” water to be sold to new irrigators and again expanding the irrigated area; (iii) abstracting less water from the source supply[6]; or (iv) some combination of the previous three alternatives. In some situations, the value of these water losses may be tempered by the fact that this seepage effectively ends up in groundwater which, in years of low natural recharge, may have some positive value.

[6] All water abstracted from the source supply, such as a river, has an opportunity cost (if extracted) or value (if not abstracted). This results from the fact that this water has other alternative potential uses, either abstractive uses at the same or other extraction locations (for example, potential use by other irrigators), or non-abstractive uses (for example, augmenting in-stream values).

### *3.9 On-Farm Irrigation Management.*

The piped reticulation system may allow a greater flexibility in on-farm water management compared with an open-channel system, depending on whether the open-channel system provides water on demand or on roster. Since the piped system will be on-demand, water will be utilised by irrigators as required, not according to the time when it is supplied, so matching the water demands of the crop. In addition, sumps or on-farm dams will not be required to smooth uniform demand when direct pumping from open-channels is difficult.

### *3.10 Improved Water Quality.*

Open races systems can involve significant problems in water quality, with leaves, grass and algae in the race system affecting farm pump operations. In addition, the temperature of the irrigation water generally increases over the length of the reticulation system increasing the potential for algal contamination and the costs associated with filtration systems. Contrast this with a piped reticulation network where water quality is preserved at the level it was at the network intake.

### *3.11 Environmental Effects.*

Open races systems do provide amenity and environmental benefits in terms of fish habitat, and refuge/breeding areas for wildlife. It is also possible to provide recreational opportunities within an open-channel network. These opportunities are forgone with the piped system.

### *3.12 Public safety costs.*

Any open channel distribution network introduces aspects of public safety, even with fenced channels and grills over culverts. Despite such precautions, there always remains the possibility of accidents and even drowning with such a large body of water – involving stock and/or humans. A further consideration is that piped systems do provide the opportunity to provide pressurized water for fire-fighting with public safety benefits.

### *3.13 Methodology and Evaluation*

The recommended approach for evaluation is to quantify all the implications of the two options (open-channel and piped) over an agreed analysis period (such as 20-30 years), recognising that some components will have an impacts every year (e.g. comparative pumping costs), some will only appear periodically (e.g. maintenance), and some will not be able to be valued in monetary terms (e.g. environmental values). These non-monetary items need to be described and quantified in as much detail as possible, because even through they cannot be priced; they are still important values and components of the decision framework.

It is then recommended that all components which can be valued in dollar terms are "discounted" to a present value, using a range of "real" discount rates[7] (say between 6% and 10%). This Present Value (PV), together with the list of non-priced effects, form the basis for the decision on which option is preferred.

[7] Since all unit prices will be in terms of a constant price datum, the discount rate will not include an allowance for inflation. As such, it will be "real", as against "nominal", and differs from interest rates prevailing in the market

It is possible that in some situations, a comparative evaluation from a private perspective (i.e. such as that of a group of farmers, for example), will yield a different result than an evaluation undertaken from the community's perspective. This is likely when considerations have different "values" from a private compared to public perspective. Examples are where seepage looses in open channels reticulation networks have groundwater recharge value – the benefits of which do not accrue to the irrigators in the scheme under consideration, but to irrigators drawing from other sections of the aquifer (which are benefits to other private individuals), or to wetlands, river flows and lake levels (which are public benefits). Similarly, where a piped system will result in water savings, these "savings" may be traded (which are private benefits), or source abstraction quantities reduced (higher river flows could augments in-stream values which are public benefits). Each situation studied will vary in this context, but it will be important to isolate where individual components have values that will differ whether perceived from a private or public perspective.

# 4.0 Economic Cost Comparisons of Pipe and Open Channel in Case Studies

The technical analyses and capital cost estimates of the detailed case studies are given in Appendixes 2, 3, 4 and 5. These sections combine results from these analyses with non-capital cost estimates to provide the economic cost comparisons.

The economic cost comparison between pipe and open-channel options follows the generic methodology outlined above, with the common assumptions applicable to each case study summarised below:

- All prices are in constant 2006 dollars;
- The analysis period adopted is 30 years;
- Base capital costs are "best estimates" and include commissioning costs but exclude physical contingencies[8];
- The options are compared in discounted cash flow framework over this period with real discount rates of 6, 8 and 10 percent; and
- Real electricity prices are assumed to rise by 1 percent annually over the next 10 years.

This generic framework is then applied to each case study as follows.

## *4.1 CPW Case Study*

The sub-area adopted in this case study covers a gross command area of 36,000 ha. The specific assumptions[9] applicable to the economic analysis of this case study are as follows:

- Implementation extends over 5 years, with the first 2 years devoted to resource consenting and initial preparatory work, and the subsequent 3 years to civil work;
- Commissioning costs add 3 percent to capital costs and are spread over years 5 of the implementation period and into Year 6, the first year of operation;

[8] Physical contingencies would need to be included as part of detailed project costings.
[9] The estimates of the cost of non-capital costs and recurring annual costs have been based on analyses of similar projects and discussions with operational schemes; and on the specific features of the case study investigations.

- Resource consenting expenditure for the open channel option occurs over years 1 and 2 of the analysis period, and involves an investment of 5 percent of base capital costs spread equally over the 2 years– the piped option involves an expenditure of 85 percent of this amount;
- Legal costs for the open channel network are assumed at 4 percent of base capital costs, equally spread over Years 1 and 2 – expenditure for the piped system is at 40 percent of this amount;
- There are no additional infrastructure costs (such as upgrades to the electricity network) associated with either option;
- The open-channel system will require the canal footprint to be purchased;
- The pipe system will require easements to be established over the reticulation footprint, the costs of which are reflected in legal costs.
- The open channel network assumes the purchase of 280 ha of land for the canal footprint, and another 22 ha of land for other minor works, or a total of 302 ha. The pipe scheme assumes 164 ha of land for land easement, with no land purchase;
- The compensation price for land purchase is $15,000/ha.
- Operational costs for both systems are $16/ha;
- Pump R&M is assumed at 3 percent of capital cost;
- Pumps are replaced after 15 years assuming 3,000 operating hours per year. With the open channel system, all 305 pumps are replaced at year 15. With the pipe system, 57 turnouts do not require pumps. Of the remaining 248 turnouts, pump replacement is programmed between years 15 to 25 depending on average usage/load.
- System maintenance costs for the open channel system are $15/ha and for the pipe system $12/ha.; and
- Water “savings” with the piped system are assessed at 20 percent of the water that would be required at the headrace of the open-channel network. This water has a “value” of $4,600/ha and is “sold” in the 2 years following scheme commissioning.

The results of the analysis with these assumptions are shown in Table 1.

**Table 1: Central Plains - Open Channel vs Pipe**

| | **Present Value Cost ($ millions)** |
|---|---|
| Open Channel System | |
| 6% discount rate | 162 |
| 8% discount rate | 132 |
| 10% discount rate | 110 |
| Piped Distribution System | |
| 6% discount rate | 118 |
| 8% discount rate | 102 |
| 10% discount rate | 90 |

This analysis indicates that the piped distribution system holds promise to be a cheaper option than the open-channel system, when evaluated over a 30 year analysis period. Although the piped system is about twice as expensive in terms of base capital costs ($123 million vs $64 million), the lower operations costs with the piped system because of the pressurised water delivery reducing on-farm pumping costs, together with the value of the water savings generated from the piped system, result in a lower-cost alternative when viewed over the longer term.

In terms of sensitivity analysis, this result is robust across all three discount rates. In addition, sensitivity testing indicates that:

- Should there be no real increase in the price of electricity over the analysis period, there is negligible change to the results because the “value” of these savings do not start to occur until after Year 6 and then only escalate at 1 percent annually for 4 years;
- Should the value of the water “savings” be negligible, then the two options become comparable in present value cost terms at the higher discount rates (8 and 10 percent);
- Should capex costs increase by 20 percent, the piped option still remains the preferred option in terms of the present value of comparative costs; and
- If pump operating costs increase by 20 percent, there is only a small change to the results, and the comparison remains similar.

### *4.2 ALIS Case Study*

The sub-area adopted in this case study is described in Appendix 4, and covers a gross command area of 4,083 ha and supplies water to 3,200 ha. The specific assumptions applicable to the economic analysis of this case study are as follows:

- Implementation extends over 4 years, with the first year devoted to resource consenting and initial preparatory work, the subsequent year to preparatory work followed by two years of civil work (Years 3 and 4);
- Commissioning costs add 3 percent to capital costs and are spread over years 4 of the implementation period and into Year 5, the first year of operation;
- Resource consenting expenditure for the piped system occurs in year 1 of the analysis period, and involves an investment of 2 percent of base capital costs;
- Legal costs for the piped network are assumed at 1 percent of base capital costs, equally spread over Years 1 and 2;
- There are no additional infrastructure costs (such as upgrades to the electricity network);
- The pipe system will require easements to be established over the reticulation footprint, the costs of which are reflected in legal costs;
- The pipe scheme assumes a network layout involving land easement, with no land purchase;
- The piped system will “release” for sale that area of land which currently forms the footprint of the open-channel network– it is assumed that 30 ha of this land will be sold in Year 5 at $15,000/ha.;

- Operational costs for both systems are $16/ha (in other words, no operational costs savings are assumed);
- Pump R&M is assumed at 3 percent of capital cost;
- Pumps are replaced after 15 years assuming 3,000 operating hours per year. With the open channel system, all 27 pumps are replaced at year 15. With the pipe system, 8 turnouts do not require pumps. Of the remaining 19 turnouts, pump replacement is programmed between years 15 to 25 depending on average usage/load.
- System maintenance costs for the open channel system are $15/ha and for the pipe system $12/ha (in other words, the pipe system has a maintenance cost saving of $3/ha.); and
- Water "savings" with the piped system are assessed at 20 percent of the water that would be required at the headrace of the open-channel network. This water has a "value" of $4,600/ha and is "sold" in the 2 years following scheme commissioning.

The results of the analysis with these assumptions are shown in Table 2.

**Table 2: ALIS replacing open channel with pipe reticulation.**

| | **Present Value Cost ($ millions)** |
|---|---|
| Piped Reticulation System | |
| 6% discount rate | 4.5 |
| 8% discount rate | 5.0 |
| 10% discount rate | 5.3 |

This analysis indicates that the piped distribution system is likely to be more expensive than the open-channel system it replaces when evaluated over a 30 year analysis period. The capital costs of the piped system are such that they cannot be offset by the savings in operations costs (reduced on-farm pumping costs), together with the value of the water savings generated from the piped system.

In terms of sensitivity analysis, this result is robust across all three discount rates. Using the 8 percent discount rate as a comparative benchmark, the base case PV of cost for retrofitting is $5M. If capex is reduced by 20 percent, this falls to $2.9M and if capex falls by 40 percent, the PV of cost falls to $0.8M. If water sales revenue increase by 20 percent, the PV of cost in the base case falls from $5M to $4.7M. In the case where opex cost savings are increased by 20 percent, the PV of the cost falls to $4.5M.

The sensitivity of the result is therefore very heavily dependent on the capital cost of the retrofitting. Appendix 5, section 10.8 details one approach to reducing the capital cost by altering the risk assumptions. If this capex is transferred across to the above analysis, the assessed PV of cost for the retrofitting option decreases from $5M in the base case (at a discount rate of 8 percent), to $1.6 M.

### *4.3 Comparison of Results*

It is informative to list some of the reasons why a piped reticulation system is apparently more cost-effective in the Central Plains scenario, whereas retrofitting a piped system into the ALIS may be less attractive from an economic viewpoint. In this regard:

- The piped network for the CPW scheme involves a base capital cost of around $3,400/ha compared with that for the ALIS at just under $4,100/ha. This is a result of the different layouts (with ALIS being a longer, narrower layout with only some of the properties supplied) and the ALIS design criteria to supply at a minimum head of 42m. Layout, however, appears to have a comparatively dominant impact on scheme cost.
- The CPW scheme has higher on-farm pumping operating cost savings for pipe versus open channel than ALIS because: (a) ALIS has a lower system capacity, with less flow being supplied to each property; (b) ALIS has a lower target pressure to be supplied; and (c) ALIS has lower electricity costs.
- The piped network for the CPW generates on-farm pump operating cost savings compared with the open channel option of around $160/ha compared with the ALIS of just under $100/ha. The CPW figure results from relatively high energy cost values for both options subtracted, whereas the ALIS figure results from a modest energy cost of the limited pumping from races at present, to the piped option where energy costs are zero, because of the high delivery pressures.

### *4.4 Additional Considerations*

It is emphasised that the economic analysis above is only part of the comparative evaluation – other aspects (both perceived benefits and costs, but parameters which cannot be quantified in monetary terms), need to be included in any comprehensive comparison. The extent to which each of these issues will apply, and the weight given to each, will vary with individual circumstances, but the following table lists some of the factors that should be also canvassed in any comprehensive comparative evaluation of the options.

**Table 3: Additional Considerations**

| System | Additional Potential Comparative Benefits |
|---|---|
| | |
| Open Channel Reticulation | Allows augmentation of lowland streams (although piped schemes can allow direct augmentation) |
| | Provides additional groundwater resource for potential abstraction |
| | Provides additional groundwater for dilution of leachates |
| | Creates potential wildlife habitats |
| | Provides more equitable on-farm pumping costs across the command |
| | Provides opportunity to collect and utilise by-wash |
| | Easier to expand in the future |
| | Creates opportunity for amenity and recreation benefits on waterways |
| | Provides for easier implementation through the improved "bankability" which attaches to lower capex. |
| | |
| Piped Reticulation | Reduces potential for water mixing with cultural and bio security implications |
| | Reduces need for rostered water delivery systems |
| | Provides pressurized water for fire-fighting |
| | Reduces access disruption to farm operations from channel bridges, culverts and fences |
| | Increases land use flexibility without channels dissecting paddocks |
| | Provides higher water quality at farm turnout |
| | Reduces need to discharge excess flows after stoppages |
| | Easier to measure scheme flows |
| | Reduces issues in health and safety |
| | Increases scheme security |
| | Reduces risk of water contaminants |
| | Less exposure to real price rises in energy costs |
| | More socially acceptable to wider community |
| | Reduces visual impacts |
| | Provides potential potable water supply |
| | Is perceived to be a more "sustainable" use of resources |
| | |

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# APPENDIX 7
# GENERIC ISSUES IN THE COMPARISON OF PIPE AND OPEN CHANNEL IRRIGATION DISTRIBUTION NETWORKS - LESSONS LEARNED FROM CASE STUDIES

## Contents

# GENERIC ISSUES IN THE COMPARISON OF PIPE AND OPEN CHANNEL IRRIGATION DISTRIBUTION NETWORKS - LESSONS LEARNED FROM CASE STUDIES

## 1.0 Purpose

The purpose of this Appendix is to provide the generic understandings gained from the case studies on the technical issues that need to be considered, when completing a comparison of open channel and pipe distribution systems in distributing irrigation water for the purposes of spray irrigating the land.

The technical issues that are broadly discussed are design criteria, hydraulic design and estimating quantities and costs

## 2.0 Lessons Learned From Case Studies -- General

### *2.1 Cost Estimation*

- The accuracy of cost estimation and reliance put on values should be reflective of the level of investigation or design the scheme is at.
- In early stage investigations scheme costs are underestimated. Often hidden costs and requirements are only considered at later stages.
- A number of unexpected costs often become exposed in detailed design.
- Effort to complete several design iterations is recommended to optimise schemes as significant savings can be made with efficient designs.
- The method of 'contract' with contractors affects scheme cost. Contracts are a risk sharing device and the more risk a contractor takes the greater the cost.
- Suppliers and contractors are often willing to assist with pricing components of projects.

### *2.2 Pipe Schemes*

- Pipe scheme cost is generally similar nation wide dependent on pipe material utilized. Alternative pipe types often come with specialized installation systems that have comparable final installed costs.

- For large schemes, often effort is put into sourcing materials from less expensive countries with minimal representation in New Zealand. Experience indicates the cost of pipes made outside New Zealand is not significantly cheaper than local products for comparable material properties. Low quality pipes can be sourced internationally (up to 50% cheaper) but carry a corresponding risk factor.
- Pipe sizes less than 600 mm can often utilize several material types. Above 600 mm the range of materials is more limited including supplier choice. Optimising pipe diameter during design can save significant costs.
- The pipe scheme case studies will provide an approximate scheme cost independent of scheme location in New Zealand. The spreadsheet was developed for gravity water supply at the intake. Pump schemes may alter pipe designs based on transient effects and the velocity versus friction loss design of the pipe.
- For schemes with frequent topographic variation a significant proportional cost will be bends and anchor blocks.
- Contractors for pipe scheme construction are limited when compared to canal construction due to specialist skills often required, such as ticketed welding or installation techniques.
- The layout of the scheme significantly affects costs. Long large diameter primary feeder pipes should be minimized. The two case studies highlighted that the overall scheme layout affects the efficiency of the design.

### *2.3 Canal Schemes*

- Canal scheme design is typically unique to the location and flow requirements, and unit costs are not easily transferred from one scheme to another.
- Local geology, topography and intake locations significantly alter the infrastructure design.
- The acceptance criterion for water losses requires consideration by developers and the appropriate Resource Consenting authority. Where seepage targets are set without regard to the available soil types and construction materials, canal lining may become prohibitively expensive or possible unfeasible from a technical viewpoint. Lining costs are a large portion of canal costs.
- Contractors and equipment for canal scheme construction are readily available and competitive prices can be obtained for construction.
- For larger canal schemes it may be appropriate to pipe smaller sub areas of the scheme rather than constructing tertiary canal systems.
- Water management of canal schemes is often more wasteful than pipe schemes. Utilising modern control systems and equipment such as automated gates for a new scheme will provide significantly improved water usages than a manual system.

## 3.0 Setting Common Design Criteria

For a fair comparison between the piped distribution and open channel it is important that, as far as possible, both options deliver water to each turnout with the same level of service. Before the outset of designing the piped distribution or open channel network, the design criteria must be clearly outlined.

### *3.1 Water Source*

For an open channel and pipe distribution comparison, the water is likely to be supplied by gravity from a race or a head pond.

- The water may be abstracted from one specific location or from multiple locations.
- There may be opportunity to locate abstraction points at different locations to reduce piping or open channel requirements. This should be considered further as part of the pipe layout optimisation.

### *3.2 Irrigated Area and Turnouts*

- Generally the total irrigated area would be divided up into smaller areas, usually properties or farms. The number of turnouts on the scheme and the flow to be supplied by each turnout will need to be quantified.
- Typically, one turnout supplies one property. Where the properties are small in area, one turnout may supply multiple properties. Large properties may require multiple turnouts. Some properties within the command area of the scheme may not wish to be included within the scheme.
- Within each property, the area used to determine turnout flows may need to be adjusted to represent the actual area on the property that will the irrigated, after taking into account buildings, roads and other non-irrigable areas. Typically a factor of 90% is applied.

The function of turnouts needs to be established. Whether they will provide pressure control, flow control and metering or other functions has to be considered.

### *3.3 Pressure Control*

When designing a pipe network, it is important to consider dynamic, static and transient (surge and water hammer) pressures and appropriate methods for pressure control. Where there are significant elevation changes throughout the network, the scheme may be subjected to high static pressures. If so, static pressure could be significantly higher than dynamic pressure and will be the main focus regarding pressure control.

- Typically lower pressure rated pipes and a lower standard of installation occurs on on-farm irrigation systems than used on municipal or scheme distribution systems, so it is important to protect on-farm systems from the risk of high pressures that may occur in the network.
- Two main options to provide pressure control are: (i) Design the scheme pipeline without pressure control to withstand full static, dynamic and transient pressures and to provide pressure control on-farm as part of the turnout. This will require higher pressure class pipe for the scheme but enable lower pressure class pipe to be used on-farm; and (ii) Provide pressure control within the scheme network in the form of pressure reducing valves or break pressure tanks. This allows lower class pipe to be used throughout the scheme but requires expensive pressure control within the scheme.
- Option 1 is preferred as the complexity of the scheme operation is reduced, lower cost control at turnouts can be used and maximum pressure is delivered to turnouts, reducing on-farm pumping. However, pipe costs are higher.
- Option 2 is more complex, has a higher risk of failure and reduces pressure delivered to the turnouts meaning more on-farm pumping requirements. In general, pressure control within the scheme should be avoided if possible.

Transient modelling is required to minimise the risk of transient pressures throughout the network. Typically transient pressures do not limit design options and usually can be mitigated through appropriate operation and management of the scheme. Therefore at the pre-feasibility stage, transient pressures should be modelled, but it is not necessary to consider transient pressure in detail.

### *3.4 System Capacity*

- The flow delivered to each turnout is usually based on a scheme system capacity, which is defined in litres/second/hectare and related to irrigation demand in the region.
- Based on the peak flow rate to be delivered to each turnout and physical or operational scheme losses in the system, the total peak flow rate for the network can be calculated.
- Whether the scheme design is to provide on-demand water to all water users at all times or whether the water is to be supplied on a roster system has to be considered.

### *3.5 Pipe and Open Channel Layout*

- Whether the pipeline or open channel layout is constrained to following road corridors and property boundaries, taking into account property owners will not be involved in scheme must be considered. Services or existing infrastructure or features that need to be avoided when determining pipe layout options must also be taken into account.
- Because pipelines will probably be buried, property owners are likely to be more amenable to pipes passing through their properties. Open races, due to their nature, will have a larger impact on property owners and will most likely be constrained to property boundaries and road corridors.
- To ensure that piped distribution and open channel networks can be properly compared, they must deliver the same level of service to each turnout. Additional pipeline (or similar) may be required on an open channel network to achieve this.

### *3.6 Turnout Delivery Pressure – Piped Option Only*

- The system needs to be designed to supply positive pressure (say a minimum of 5 m) to all turnouts, ideally without the need for in-scheme pumping. This reduces the risk of negative pressures developing.
- Whether the minimum pressure is set higher than 5 m, for example, where the pressure delivered (if possible) to the turnouts is sufficient for irrigation systems to operate effectively without on-farm pumping, depends on the trade-off between scheme pipe capital cost and on-farm pumping cost. An effective way of examining this is to calculate a net present value (NPV) for the scheme and on-farm pumping and choose the option with the lowest NPV.

### *3.7 On-Farm Pumping*

- To operate an on-farm irrigation system effectively, a minimum pressure will need to be supplied, which for pre-feasibility studies, should be based on typical irrigation system pressure requirements. For example, a typical spray irrigator requires approximately 40 m pressure at the hydrant to operate effectively. Assuming there is 10 m pressure loss due to friction within the on-farm pipeline, then the turnout pressure would need to be 50 m.
- With an open channel network, delivery pressure is effectively zero and pumping from the open channel will be required to deliver the necessary turnout pressure to the irrigation system.
- With a piped gravity system, water will be supplied to each turnout under pressure. However, due to friction losses or changes in elevation along the pipe network, some on-farm pumping may be required at times in some locations.
- To aid in the assessment of on-farm pumping requirements for both open channel and pipes systems, land use projections and monthly and seasonal irrigation demand estimates are required. These will form the basis for the change in irrigation demand through the irrigation season and will be the criteria used for determining the operational costs for on-farm pumping.

## 4.0 Hydraulic Design

### *4.1 Pipe Layout and Sizing*

The pipe layout is determined by completing a preliminary hydraulic analysis under various options to maintain positive turnout pressures if possible and to provide approximate pipe diameters and cost for each option. Cost is usually used to rank layout options. Once an acceptable layout is determined, a detailed hydraulic analysis is completed to finalise the pipe diameters of the network to ensure all design criteria and appropriate design limits are met.

### *4.2 Pipe Layout*

#### 4.2.1 Contour Information

The level of detail for the contour information entered into the modelling software needs to be appropriate for the region. For example, on gradually sloping plains (e.g. Canterbury Plains) 10 m contours may be acceptable as the interpolation between these contours is going to give a reasonable estimation of the lie of the land between the contours. However, in North Otago on the rolling downlands, a higher level of contour information may be required as interpolation between the contours may not be representative of the lie of the land.

#### 4.2.2 Water Source

When the scheme water source is from a main race, multiple water supply takes from the water source should be considered. This may have the advantage of allowing some properties near the top of the scheme to be supplied directly from the water source. Also the main water supply location point may adjust so that it is closer to the majority of turnouts, which will reduce the length of larger diameter pipe required.

## *4.3 Turnouts*

Laterals branching off from the main supply pipe should be used to supply the turnouts. The number of laterals to supply water to the turnouts can be reduced by relocation of the turnouts. For example, to deliver water to four adjacent properties if the turnout is located at the high point on the properties then two lateral pipes are likely to be required, whereas if the turnouts can be repositioned it may be possible to deliver all four properties by one larger pipe which is likely to be more cost effective. This is possible only if there is flexibility in the turnout location.

## *4.4 Pipe Layout*

To optimise the pipe layout various pipe layouts need to be modelled. In doing this approximate pipe diameters should be determined, thus enabling the total pipe capital cost to be estimated.

Using pipe network modelling software, pipe diameters throughout the entire network can be initially sized based on water flows not exceeding a specified velocity. This is considered an appropriate method for selecting a pipe layout, as it provides a quick assessment of the pipe diameters and costs required throughout the network for different layouts. Using software, this method is repeatable and should provide for a consistent and comparative approach for assessing the different layouts. A full hydraulic analysis is required to finalise pipe diameters within the network (see Section 4.6). This is not considered necessary for comparative assessments of the different layouts in the initial stages.

## *4.5 Using Gravity for Maximum Benefit - Maximum Velocity*

For schemes with significant fall from top to bottom of the scheme, the elevation change over the length of the pipe network may allow higher velocities to be used, as the change in elevation supplies pressure in the system. This enables smaller diameter pipes to be selected, as the elevation gain largely offsets the additional friction losses within the smaller diameter pipes.

If the velocity is too high, pipe friction losses will exceed pressure gains due to gravity, meaning that the pressure within the pipeline could become negative or zero, or the cost of on-farm pumping may become excessive. Also, the risk of water hammer and problems with transient pressures increases significantly at high velocities.

If the allowable maximum velocity is too low, pipe diameters and hence pipe cost will increase significantly. Further, minimal reductions in on-farm pumping costs are often achieved, ultimately increasing the total NPV of the network.

When setting a maximum velocity, trial a couple of scenarios, bearing in mind that a maximum velocity may need to be set to reduce the risk of water hammer (e.g. 3 m/s). Aim on basing the velocity on supplying positive pressure to the majority of turnouts and on pressure increasing down the network within the main supply pipe. This approach means that typically no further adjustment will be needed to the main supply pipes and only pipe diameters on the laterals need to be adjusted to ensure all turnouts receive positive pressure (described in Section 4.6).

The trade-off with this approach is that more on-farm pumping is likely to be required than if the pipe diameters were selected based on a lower velocity. Therefore it is important to consider both capital and operational costs when considering the final costs of a scheme.

This is investigated further in Section 4.10 where the NPV for the entire network is considered to determine the trade-off between pipe capital cost and on-farm pumping cost.

### *4.6 Pipe Diameter*

Once the layout is finalised, diameters of the pipes can be determined.

- Check that velocity within pipes is within acceptable velocity limits to reduce the risk of water hammer.
- Check that the dynamic and static pressure within the pipelines are within pipe pressure class limits.
- Check that the minimum pressure is supplied to all turnouts.

### *4.7 On Farm Pumping*

- The turnouts that require on-farm pumping need to be identified and the pump size determined based on supplying the agreed turnout pressure at peak load. In areas of high irrigation demand and on smaller schemes with low numbers of turnouts, peak load may be based on 100% demand.
- In schemes with lower irrigation demand, with high numbers of turnouts and a wide variation of crop types, a lower figure such as 90% scheme demand or 80% scheme demand may be preferred.
- The network is then modelled under different loading to calculate the energy costs related to on-farm pumping.

### *4.8 Pump Size*

From the modelled scheme delivery pressure data under peak load conditions, the turnouts that require on-farm pumping can be identified by comparing the minimum on-farm pressure specified to operate the irrigation system with the scheme delivery pressure. The additional pressure required to supply the on-farm pressure is calculated. This data is used to size the pump for each turnout.

For the open channel option, a standard soft-start surface pump should be sufficient as pumping pressure requirements are generally fixed. Either the system is running or it is not and there is little variation in the pump power required throughout the season.

For the piped option, variable speed drive pumps should be considered due to the large variation in pump pressure requirements experienced at the turnouts throughout the season.

### *4.9 Pump Operational Costs*

To enable seasonal pumping costs to be calculated, model the pressure delivered to each turnout using the average monthly flow demand for each month. Based on the average monthly flow demand, calculate the number of hours that the turnout would have been operating at maximum flow within that month.

Using the maximum flow and operating hours per month, the monthly on-farm pumping requirement can be calculated, thus giving the total season pumping energy use.

### *4.10 NPV*

When designing the scheme and finalising the pipe diameters, it is important to consider both capital and operational costs, to establish a relative total cost of the scheme. This can be done by calculating the NPV.
Based on the pipe diameters determined in the design process, the pipe lengths and pipe class are known and pipe capital costs can be calculated.

Using the total seasonal energy use and energy price to determine energy costs and adding in other annual costs such as maintenance and operational costs, calculate the net present value of the annual costs based on a representative discount rate over an appropriate period of time.

Add the pipe capital cost and other capital costs to the net present value of the annual costs to determine the total cost of the scheme. Note that it is not necessary to include all scheme costs for this assessment if they are the same for all options. Only differences should be included.

Adjust the pipe diameters based on a lower or higher velocity, or manually following the steps described above and recalculate the capital costs and annual costs and compare. Continue performing these iterations until the lowest NPV is established.

# APPENDIX 8
# SOCIAL, CULTURAL AND ENVIRONMENTAL ISSUES

## Contents

# SOCIAL, CULTURAL AND ENVIRONMENTAL ISSUES

## 1.0 Purpose

This report addresses the key output described in Milestone 4a.

> **Milestone 4a: Public Benefit Issues:** Convene, hold and report on community/stakeholder workshops to identify the social, environmental and cultural benefits and issues around the alternative distribution systems.

The purpose of this document is to report the results of the consultations. Where workshop participants are quoted verbatim, their comments appear in italics.

### *1.1 Approach*

The approach used for the consultation was to run two small-group workshops in the heart of the Central Plains Water case study area. The workshops were held at Hororata, one in the evening and one in the morning. A range of community members were invited to participate in whichever of the two workshops best suited them.

To help participants prepare for the workshops, invitation letters included the following:

> From the workshops we wish to gain a better understanding from rural community people, farmers and stakeholders of the social, environmental and cultural issues both for and against piped and open channel distribution systems for large-scale water enhancement projects.
>
> **QUESTIONS TO THINK ABOUT:** Two questions you might like to think about before the meeting are:
>
> From social, environmental and cultural perspectives –
>
> 1. What do you see are the pros and cons of open channel water distribution systems?
> 2. What do you see are the pros and cons of piped water distribution systems?

The workshop approach involved two components**.**

- Firstly an open workshop process with participants discussing their understanding of and attitudes towards the alternative water distribution systems. To help participants understand the two distribution alternatives a presentation was made by Dr Terry Heiler to provide information on how the two systems would operate in the case study area and to explain the technology.
- The second component involved providing participants with a worksheet on which they were invited to record any key messages or issues they wished. At the end of the workshop the worksheets also asked participants to nominate their preferred water distribution system and to list the key influencers/factors contributing to their decision.

## 2.0 Results: The key social, cultural and environmental issues of pipes versus open channels

Participants of both workshops readily identified pros and cons of both distribution systems with consistently the same issues expressed at both workshops. The majority of issues presented were either **for pipes** or **against open channels,** and were predominantly the antithesis of each other, as shown in the Table 1 below.

**Table 1: Workshop outcomes: The key social, cultural and environmental issues of pipes versus open channels.**

| **Pipes - For** | |
|---|---|
| | • *Safety good*<br>• *Environmentally friendly*<br>• *Aesthetically friendly*<br>• *Water 365 days for:*<br>  o *Stock water*<br>  o *Fire fighting (some under pressure)*<br>  o *Wetlands*<br>  o *Ponds*<br>• *Long term Energy saving - water delivered under pressure to some farms means no or little pumping*<br>• *(Pressurised) water during power cut*<br>• *Less land loss*<br>• *More flexibility re placement and location of line*<br>• *Access easier – no limitations*<br>• *Less disruption to farming – access*<br>• *Flexibility of location / line (road side shelter)*<br>• *Long term (once capital paid)*<br>  o *Greater balance of farm types – more chance to pay if water under pressure*<br>  o *Energy saving (less pumping)*<br>• *Social benefit - potential to supplement rural domestic and stock water year round*<br>  o *Use as grey water*<br>  o *Use in townships*<br>• *Water saving*<br>  o *Less pressure on river*<br>  o *Less storage or irrigate more land*<br>• *Water quality advantage*<br>• *More socially acceptable - lower social upheaval* |

| | |
|---|---|
| | • *Access – uphill and around significant features*<br>• *Saving on bridging costs* |
| **Pipes - Against** | |
| | • *High upfront capital costs*<br>• *May be greater disruption installing across farms*<br>• *Earthquake risk higher*<br>• *If pipes replace channels, may lose environmental habitat and biodiversity (can be retained at a cost outside irrigation scheme)* |

| **Open Channels - For** | |
|---|---|
| | • *Potentially turbines to generate electricity, e.g. Mid Canterbury*<br>• *Improves aquifer recharge*<br>• *Environmental and biodiversity opportunity – only achieved if the channels flow year round which is not proposed in the CPW case study (flow during irrigation season only)*<br>• *Possibly warmer water*<br>• *Cheaper capital cost*<br>• *Easier to expand in the future* |
| **Open Channels - Against** | |
| | • *Safety – drowning*<br>• *Access problems (and resulting increased use of roads for farm travel)*<br>• *Loss of land to individual, potentially cutting through properties, especially effecting lifestyle blocks*<br>• *Land out of production – especially reducing small block size*<br>• *Loss of shelter belts*<br>• *Moving power lines*<br>• *Removal of vegetation*<br>• *Moving buildings*<br>• *Water loss – leakage & evaporation*<br>• *Poorer water quality to farms*<br>• *Environment - canal vulnerable to pollution/contamination (chemicals, fuel and sediment)*<br>• *Sabotage risk*<br>• *By-wash water quality issues (N)*<br>• *High energy use – water pumping required on farms*<br>• *Less harmonious community process*<br>• *Land transactions - unwilling land-sellers – high land purchase cost*<br>• *Maintenance higher and who is responsible?*<br>  o *Road frontages*<br>  o *Weed problems*<br>• *No water in winter*<br>• *Young fellows*<br>  o *Winter racing dry canals*<br>  o *Summer Jet skis!*<br>• *Noise of channels*<br>• *Potential loss of scheme shareholders if wells are recharged* |

The key benefits of the piped distribution system can be summarised as a wide range of community benefits and opportunities, land savings, energy savings and water savings.

## *2.1 Social, Cultural, Environmental and Economic Benefits – Sustainability*

Attempts to separate issues into either environmental or social/cultural were in most cases difficult due to the high level of overlap between the two categories. Key issues identified as fitting these categories were:

## *2.2 Environmental*

- *Mud fish – habitat comes with water = either system*
- *Winter problems with dry open channels*
    - *Empty canals smell?*
    - *Dust?*
- *Didymo in channels?*
- *Unknown effect of surface area of water from channels*
- *Fish screens out of headrace an issue for pipes and channels*
- *Water savings from pipes available for community parks and reserves*

## *2.3 Social/Cultural*

- *Pipes are less invasive (lower visual impact) to non-irrigators community members. i.e. out of sight, out of mind*
- *Benefits of scheme to wider community (easier access with pipes)*
    - *Domestic garden water supply*
    - *Lifestyle block water supply*
- *Intergenerational opportunities*
- *Potential for potable water – high quality standard*
- *Water quality better with pipes*
- *Pipes*
    - *Energy efficient*
    - *Carbon credits*
    - *Efficient use of water*
- *Water savings from pipes available for community parks and reserves*
- *Headrace recreational opportunities*
    - *Maximise – bridges high enough for boats to pass under*
- *Present stock water – include into irrigation scheme and get savings and priority water*
    - *Maintenance savings*
    - *Water savings*
    - *Land savings*
    - *Increased water quality with troughs*

A significant outcome of the workshops was that the majority of the piped distribution benefits could not be classified as just social or cultural or environmental benefits, but did in fact cross two or all of these classifications and in many cases offered economic benefits as well. Good examples were energy savings, achieved by having water delivered to farms under pressure in pipes and thus reducing or eliminating the need for pumping, and water savings, achieved by piping and giving the benefits of lower extraction, less storage volume and/or more water for irrigator and community use. The conclusion being that piped distribution offered the all-encompassing benefits of **SUSTAINABILITY.**

## *2.4 The Key Influencers*

Toward the end of each workshop all participants were asked to nominate their preferred water distribution system and to list the key influencers/factors contributing to their decision. Responses were written on the anonymous worksheets.

**Table 2: Have you made a decision of a preferred water distribution system?**

| Total participants | Open channels | Pipes | Undecided |
|---|---|---|---|
| **32** | **0** | **31** | **1** |

The participants who preferred pipes recorded the following key influencers contributing to their decision (grouped into common themes):

- Land saving, no wastage, minimal loss of productive land
- Smaller footprint, minimal intrusion, more versatile
- Greater variety of land use
- Access easier
- Safety (road and children)
- Environmental benefits
- Social benefits
- Aesthetic benefits
- Energy efficiency, water under pressure on-farm, will counter future power price increases, potential power generation
- Water efficiency, conservation and lower losses
- Water quality, no pollution
- Increase in ground water flows
- Water 365 days
- Opportunity to provide farm and community needs other than irrigation (fire fighting, stock water, household water, intensive horticulture)
- Better long term outcomes for local and New Zealand communities
- Less disruption for community and farming systems
- Higher acceptance by wider community
- Ease of consenting
- Longevity, lower maintenance and running costs

The one undecided participant noted that open channels have potential ecological and amenity benefits, but qualified this for irrigation channels by saying:

1. *Most potential values of channels for biodiversity/ecological and/or amenity values do not exist if water is only in channels over irrigation season.*
2. *In general, piped systems more efficient, therefore could mean less pressure and impact on the rivers by way of less abstraction*

### *2.5 Wrap-Up Final Messages*

The final worksheet question asked for; 'Any final messages for us about piped vs open channel water distribution?' Responses were:

- *Bring it on – quicker the better*
- *Cost important, must be profitable, way funding is structured is important*
- *Pipe the scheme – we are building a scheme that will last for generations – build the cost into the generations through loans – maybe outside investors*
- *Farm access will be appalling with open channels*
- *Stock Water races*
- *Go for pipes*
- *The social and environmental benefits of piped schemes need to have some funding benefits outside of farmers*
- *The flow on benefits of piped scheme benefit whole community*
- *Room for government assistance to achieve long term result*
- *Need to "comparatively value" non-financial benefits (social, environmental and national benefits) then prepare rational for community to pay something for these benefits*
- *Get this message to government – MAF, ministers, local and central government. Talk to them about intergenerational costs and how this can be funded e.g. interest only, underwriting etc*

Of note are the responses from several people volunteering suggestions of how to overcome the high capital cost of pipes to deliver an affordable and profitable irrigation scheme. The opportunity for a piped irrigation scheme to offer benefits to the wider community over many generations was an important issue discussed at both workshops. To achieve these benefits, intergenerational funding of the higher capital costs of a piped distribution system was seen as fundamental to achieving the benefits and outcomes sought.

# APPENDIX 9
# REPORT OF MEETING ON PIPES

# APPENDIX 9 -- REPORT OF MEETING ON PIPES/OPEN CHANNEL PROJECT

This document is a general report of the meeting called to discuss the unedited draft report of SFF Project 05-117 held at MAF policy offices in Christchurch in June 2007. The attendees at the meeting are given in Annex 1 to this appendix. The comments and suggestions recorded here are not attributable to any attendee – rather they came forward in general discussion.

The main suggestions for additions and clarifications from the meeting have been incorporated in the final report.

## 1.0 Agenda

The agenda for the meeting and a hard copy of the unedited draft report were issued to all attendees several weeks before the meeting. Given this, the presentations given were focused on the generic findings, and details of case studies used to inform the generic aspects were discussed in detail in the open forum.

The purpose of the meeting was to:
(a) present the methodology used and results of the study;
(b) to get feed back on details and have a discussion with a view to finalizing the report; and
(c) to discuss the dissemination of the work to a wider audience.

The introductory presentation involved members of the study team:

| | |
|---|---|
| Dr Terry Heiler, Heiler and Associates Ltd | Project Manager |
| Dr Nick Brown, Economist | Economic Methodology |
| Rose Edkins, Aqualinc Research Ltd | Piped Distribution |
| Craig Scott, Riley Consultants Ltd | Open Channel Distribution |
| Sue Cumberworth, The AgriBusiness Group | Social, Cultural, Environmental |

Open Forum Chair (Terry Heiler) – Discussion, Questions and Answers

## 2.0 Suggested Additions to Report

**Seepage Losses from Open Channels**
**Issue**: The seepage losses in open channel systems may create benefits that have not been identified strongly enough – for example, recharge of groundwater, additional dilution of leachates and habitat creation. The financial benefits of saved water depend on quantum and this is difficult to make reliable ex ante estimates. Comment should be added to report.
**Response**: This will be done.

**Economic Analysis**
**Issue**: Scheme feasibility depends on technical, environmental, financial, economic and bankability issues and decisions should be based on as assessment of all these aspects – not just lowest long run costs. These aspects will be scheme specific, not generic. Comment should be added to report.
**Response:** This will be done.

**Sensitivity Analysis of Economic Cost Estimates**
**Issue**: Further analysis of the critical assumptions in determining economic cost needs to be done.
**Response:** The economic analysis will be extended to incorporate the sensitivity to key assumptions.

**Cost of Land Purchase**
**Issue:** It is not clear that the cost of land purchase has been incorporated in economic cost analysis.
**Response:** Has been included but will make that clearer in report.

**Future Expansion**
**Issue:** Costs will be less for open channels if there is later expansion of the scheme area.
**Response:** Agreed and a comment will be added to this effect.

**Opportunities for Reducing Piped Costs**
**Issue:** Adopting a lower level of design standard – as for ALIS case study -- will reduce costs and increase risks.
**Response:** A comment will be added to report to this effect, noting the difference between the ALIS case study and particular designs being currently investigated for the ALIS

# 3.0 Comments on Case Studies

**Design Flows**
**Issue:** Have pipe sizes and open channel capacity been based on the assumption that design flows will be 80% of peak demand or 100%?
**Response:** The case studies have assumed 100% of peak demand, but final designs may adopt a lesser percentage – this would reduce pipe costs more than open channel costs.

**Incorporation of Depreciation in Economic Cost Analysis**
**Issue**: The question of incorporating a sinking fund allowance for replacement in the economic cost analysis was raised.
**Response**: Extensive enquiries of water supply and irrigation entities, and advice from the economic analyst suggested that the most realistic way to accommodate this issue was to allow for sufficient annual costs to maintain function and integrity of the systems for the length of the economic analysis period.

**Cost of Additional Electrical Transmission Facilities**
**Issue:** The relative cost of extending power network for each option needs to be incorporated.
**Response:** This item will be common to either option, and the costs less for piped option, so conclusions will not been affected.

**Community Preferences**
**Issue:** Despite the preferences expressed by farmers for piped distribution at workshops, the question “how much extra are you willing to pay for a piped system? needs to be asked at some stage.
**Response:** The community attitude investigation was to tease out the community attitudes about the social, environmental and cultural aspects, without regard to financial implications.

**Appropriating Benefits**

**Issue:** The substantial savings in costs for electrical energy under piped distribution are not evenly enjoyed by all users, and are not immediate benefits to scheme developers – finding a way for scheme developers to fairly appropriate these benefits will be a challenge.

**Response:** Agreed, but pricing mechanisms can be devised to reflect this equity issue.

**Pressure Rating of Pipes**

**Issue:** Pressure loadings in the piped system under transient conditions will need to be incorporated in final design and may require higher pressure classes that assumed.

**Response**: This would be an essential aspect of final design. Previous detailed studies for Barrhill showed that the shut off static pressures were more demanding than transients, but this will be scheme specific.

**Risk Analysis**

**Issue:** Final design will require a formal risk analysis for each option.

**Response:** Agreed but not relevant for the brief.

**Best Use of Gravity Potential**

**Issue:** Specific schemes may be best served by a mix of open channel and piped systems.

**Response:** Agreed, but not investigated.

**Operational Losses**

**Issue:** Investment in automated control systems could reduce operational losses in open channel options.

**Response:** This is a detailed design aspect, but insufficient allowance was made in case studies for structures needed to avoid operational losses, and hence costs would be greater if included.

**Lining Cost**

**Issue:** The assumptions as to need for lining and specifications have a considerable influence on costs.

**Response:** The selection of an open channel system that operates without grade control, as requested by URS, influences the study decision as to lining requirements and specifications – more geotechnical information would be needed to contra-indicate this assumption.

# 4.0 Assessment of Meeting

The meeting provided the opportunity for major stakeholders to participate in an open forum with the project team, and the discussions were open, frank and positive. The suggestions and comments made have been recorded and where appropriate, incorporated in the final report. This record is a valuable addition to the final report and will be of use to those using the report in specific project circumstances.

**Annex 1: Meeting Attendees**

| | |
|---|---|
| Dr Terry Heiler | Heiler and Associates Ltd |
| Dr Nick Brown | Economic Consultant |
| Rose Edkins, Ian McIndoe & John Bright | Aqualinc Research Ltd |
| Craig Scott | Riley Consultants Ltd |
| Sue Cumberworth | The AgriBusiness Group |
| Ross Keeley & Geoff Stevenson | The Ritso Society |
| Claire Mulcock | Mulgor Consulting |
| Katherine McCusker | MAF, SFF |
| Derek Crombie, Doug Catherwood & John Donkers | Central Plains Water Ltd |
| Doug Marsh, Viv Smart, & Denis O'Rourke | Central Plains Water Trust |
| Tony Davis | Amiantit/Maskells |
| John van Polanen | Ashburton Lyndhurst Irrigation Scheme |
| Hock Yeo | Beca |
| Walter Lewthwaite & Cliff Tippler | URS |
| Brian Ellwood | Meridian |
| George Griffith | ECan |
| John Wright | Barrhill Chertsey Irrigation Ltd |
| David Viles & Todd Mead | Hurunui Irrigation Scheme |